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(54) Title: SUCCINIMIDE AND MALEIMIDE DERIVATIVES AND THEIR USE AS TOPOISOMERASE II CATALYTIC INHIBITORS

(57) Abstract: Maleimide and succinimide derivatives were found to be effective topoisomerase II catalytic inhibitors. Due to this property, the maleimide and succinimide derivatives were investigated for their use as cytostatic agents and thus in the treatment of cancer. The compounds of the invention can be used in combination treatments with other cytostatic agents, such as topoisomerase II poisons. The maleimide and succinimide derivatives, due to their effective topoisomerase II catalytic inhibitory activity, are also useful as extravasation agents, such as upon administration of a topoisomerase II poison.



WO 02/078679 A2

## **SUCCINIMIDE AND MALEIMIDE DERIVATIVES AND THEIR USE AS TOPOISOMERASE II CATALYTIC INHIBITORS**

### **FIELD OF INVENTION**

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The present invention relates to maleimide and succinimide derivatives, including succinimide dimers linked by a tether, which act as topoisomerase II catalytic inhibitors. In particular, the present invention relates to the use of these compounds in the optimisation of anti-cancer treatment using currently used cytostatic agents which act as topoisomerase  
10 II poisons. The aims are to provide novel cytostatic agents for cancer treatment, to broaden the therapeutical index of classical anti-cancer agents, such as anthracyclines and epipodophyllotoxines, to reduce side effects caused by classical anti-cancer agents, such as extravasation.

### **15 GENERAL BACKGROUND OF THE INVENTION**

The topoisomerase II enzymes belong to a family of nuclear enzymes involved in the processing of DNA during the cell cycle. The essential nuclear enzyme topoisomerase II allows the separation of intertwined DNA strands by creating a transient double strand  
20 break in the DNA backbone thereby allowing the passage of another intact DNA double strand through the cleavage.

Topoisomerase II is the target of some of the most successful anti tumour agents used today, e.g. the epipodophyllotoxins etoposide (VP-16) and teniposide (VM-26) in the  
25 treatment of testicular and small cell lung cancer (1) and the anthracyclines.

The anthracyclines comprise a group of widely used cytotoxic compounds with activity in numerous malignant diseases. Daunorubicin and doxorubicin, the first anthracycline antibiotics to be discovered in the early 1960's, have a wide range of activity against  
30 malignant diseases - daunorubicin primarily in the field of haematological malignancies and doxorubicin against solid tumours. Epirubicin is a stereoisomer of doxorubicin with the same indications but slightly lesser potency and less cardiac toxicity than the parent drug. Idarubicin resembles daunorubicin. It is more lipophilic than the other anthracycline compounds and penetrates the blood-brain barrier more readily.

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Drugs acting on topoisomerase II are divided into two main categories; topoisomerase II poisons and topoisomerase II catalytic inhibitors.

The topoisomerase II *poisons* shift the equilibrium of the catalytic cycle towards the cleavage of the DNA strands, thereby increasing the concentration of the transient protein-associated breaks in the genome (2). That is to say, they trap the cleavable complexes, which converts the essential topoisomerase II enzyme into a lethal one (3). Topoisomerase II *poisons* stabilise the cleavable complex by halting religation of the DNA in turn leading to the accumulation of the lethal double strand DNA breaks in the cell genome. There is solid evidence that etoposide, as well as a number of other clinically successful anti tumour agents such as daunorubicin and doxorubicin (4), are topoisomerase II poisons (5, 6). Although the precise cell killing mechanism is unknown, an obligatory step for the cytotoxicity of topoisomerase II poisons is related to an increase in cleavable complexes formation between DNA and topoisomerase II in treated cells (5).

The topoisomerase II *catalytic inhibitors* act through an entirely different mechanism. Rather than stimulating the cleavable complex, these drugs act by inhibiting the overall stages in the catalytic cycle than poisons do, acting on the topoisomerase II / DNA complex at stages in the catalytic cycle where DNA is not cleaved. This happens in at least two ways: (i) by inhibiting the binding of topoisomerase II to DNA, thereby suppressing the interaction between the enzyme, the topoisomerase II targeting drug and the DNA. This is believed to be the case for chloroquine (7) and aclarubicin (8,9); (ii) by locking topoisomerase II in its closed-clamp step after religation, which is the mode of action of the bisdioxopiperazines including ICRF-187 (10-14). By locking the enzyme in its closed clamp formation, the bisdioxopiperazines hinder topoisomerase II poisons from exerting their cytotoxicity. The catalytic inhibitor of topoisomerase II, ICRF-187, abolishes both DNA breaks and cytotoxicity caused by the topoisomerase II poisons etoposide and daunorubicin (15).

The term "extravasation" is intended to relate to the escape of a chemotherapeutic drug from a vessel to the surrounding tissue, which may occur either by leakage or direct infiltration.

In cancer treatment, accidental extravasation is a feared complication, especially from drugs such as the anthracyclines, mitomycin, vincristine, and vinorelbine, which are examples of vesicant drugs. Vesicant drugs cause tissue destruction upon infiltration. Extravasation is the unintended presence of a vesicant outside the vascular bed or vasculature.

The term "anti-extravasation agent" is intended to mean a compound which blocks or attenuates the local tissue toxicity caused by a vesicant.

Accidental extravasation has been estimated to occur in up to 6% of all patients receiving chemotherapy. Chemotherapeutic agents, such as the anthracyclines, are especially prone to cause severe tissue damage on extravasation. The tissue injury may not appear for several days or even weeks but when it appears it may continue to worsen for months, probably due to drug recycling into adjacent tissue. The local toxicity is characterised by acute pain, erythema, and swelling at the extravasation site and it often progresses to ulceration.

- 10 The present investigators have demonstrated, in animal studies, as well as on patients, that treatment with ICRF-187 protected against anthracycline extravasation injuries (19-21).

The bisdioxopiperazine ICRF-187 (dexrazoxane) is the water-soluble (+)-enantiomer of racemic (+/-)-ICRF-187. ICRF-187 is approved for clinical use (Cardioxane®) against anthracycline induced cardiotoxicity.

- A hypothesis has been that ICRF-187, as an analogue of the cation binder EDTA, protects against free radical damage by binding to  $Fe^{++}$  and thus concealing iron from oxygen (16). However, the present investigators have recently demonstrated that cells with acquired resistance to ICRF-187 carry mutations in topoisomerase II $\alpha$  (an isoform of topoisomerase II) which maps to different regions in topoisomerase II than those induced by topoisomerase II poisons such as daunorubicin and etoposide. The use of conditional expression of human topoisomerase II in yeast as well as characterization of purified topoisomerase II containing these mutations have confirmed that these mutations are functional (17,18). On this basis, it was concluded by the present investigators that ICRF-187 is a specific topoisomerase II agent.

- Two models illustrate the use of catalytic inhibitors in pharmacologic regulation of topoisomerase II poisons (22). (I) A targeted high-dose treatment with etoposide based on physiological differences between normal (non-malignant) tissue and solid tumours may be achieved using the basic catalytic inhibitor chloroquine. At normal pH (in normal tissue), the chloroquine will (in its uncharged form) cross biomembranes thereby protecting the tissue from the poisonous attack. In cancer cells with weak acidic extracellular micro environment, the partly ionised catalytic inhibitor is no longer able to pass biomembranes, thus leaving the cancer cells exposed to the cytotoxic effect of the poison.

(II) Using ICRF-187, compartment directed high dose treatment with etoposide was obtained in the central nervous system (CNS) in a mouse model. In this case the

protection of the peripheral tissue by the catalytic inhibitor is based on differences in lipophilicity between ICRF-187 and the topoisomerase II poison etoposide. Studies concerning patients suffering from primary cancer outside the CNS show that about 25% of the patients develop brain metastasis. The risk of developing metastasis is dependent on the specific cancer form. The metastatic complications may be the patient's first symptom of cancer and may then produce serious neurological complications. Due to poor accessibility of the currently clinically used topoisomerase II poisons into the brain, the need for development of new catalytic inhibitors allowing dose escalation and thereby enhanced CNS effect is urgent.

10

The use of the catalytic inhibitor ICRF-187 in accidental extravasation caused by anthracyclines is yet another example of reducing the side effects of topoisomerase II poisons hereby optimising the overall treatment of the patients. It is one object of the present invention to provide more compounds suitable for reducing side effects caused by

The use of super lethal doses of topoisomerase II poisons in combination with catalytic topoisomerase II inhibitors have proven an interesting strategy in the anticancer treatment. Selectivity can thus be obtained indirectly by the development of catalytic inhibitors capable of protecting specific targets thereby exerting the protective effect. Due to the non-optimal profile of the known catalytic inhibitors (toxicity, PK-properties etc) highly specific protection / cytotoxicity restriction is not obtained at present. Therefore there is an urgent need for the development of new catalytic inhibitors for use in the pharmacological regulation of topoisomerase II poisons in anti cancer treatment.

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Thus, the use of novel catalytic inhibitors of topoisomerase II included in the present invention will improve the anti-cancer treatment obtained with the classical topoisomerase II poisons resulting in a broader therapeutic index for these drugs by reducing the side effects (toxicity) or by enhancing the effect of the poison obtained by dose escalation.

30 There is also a urgent need for new compounds which are effective cytostatic or cytotoxic agents, themselves, in the treatment of cancer. A further aspect of the present invention is to provide for this need by providing compounds which are effective catalytic inhibitors of topoisomerase II and therefore effective chemotherapeutic agents in themselves. In this context novel compounds have been developed in order to obtain more effective catalytic  
35 inhibitors of topoisomerase II.

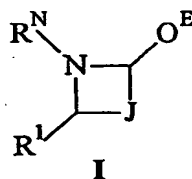
In testing the hypothesis that thiol-modification of DNA-bound topoisomerase II by quinones was involved in the stimulation of topoisomerase II-mediated DNA cleavage, Wang et al (28) tested a number of alkylating agents including quinones, N-ethylmaleimide

- (NEM), Disulfiram, and 2,2'-dithiobis-(5-nitropyridine) derivatives for their ability to stimulate topoisomerase II-mediated DNA cleavage. The results led Wang et al to postulate that these compounds act as topoisomerase II poisons by means of a Michael-addition to the enzyme. The present inventors have likewise examined the potential use of
- 5 the thiol-reactive compounds maleimide and its N-substituted derivatives n-methyl-maleimide (NMM) and N-ethyl-maleimide (NEM) as topoisomerase II catalytic inhibitors. They have found that maleimide, NMM and NEM are potent catalytic inhibitors of purified human topoisomerase II  $\alpha$ . Maleimide and NEM are also able to antagonize etoposide induced topoisomerase II mediated DNA double strand cleavage in the test tube.
- 10 Maleimide is further capable of protecting intact cells from etoposide induced DNA damage as well as from etoposide induced cytotoxicity. Finally, at-MDR cell lines with reduced nuclear topoisomerase II content are fully sensitive to maleimide, indicating that it is not a topoisomerase II poison *in vivo*. These findings provide strong evidence that these compounds acts as topoisomerase II catalytic inhibitors and not as topoisomerase II
- in vitro* and *in vivo* is caused by covalent modification of topoisomerase II cysteine residues reducing the amount of catalytically active enzyme sensitive to the action of topoisomerase II poisons, opening up for their use as novel topoisomerase II catalytic inhibitors. The inventors have further developed a new maleimide analogue TT0043 capable of
- 20 antagonizing the cytotoxic effect of topoisomerase II poisons using cultured human cancer cells. The use of such novel thiol-reactive maleimide derivatives as catalytic inhibitors of topoisomerase II thus constitutes an important aspect of the present invention.

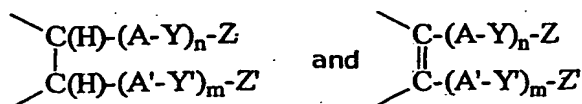
## SUMMARY OF THE INVENTION

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In a first aspect, the invention relates to the use of a compound of formula I, quaternary ammonium salts thereof, or compositions comprising either entity, for the preparation of a human topoisomerase II catalytic inhibitor,



wherein -J- is selected from the group consisting of



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$-O^E$  is a carbonyl equivalent such as selected from the group consisting of  $=O$ ,  $=S$ ;  $-OR^2$ ,  $-SR^2$ , dithiane and dioxolane;

$R^1$  is selected from the group consisting of  $-O^E$ ,  $OR^2$ ,  $N(R^N)(R^N)$ ,  $S-R^2$ ,  $NO_2$ ,  $-CN$ , and halogen;

- 5  $R^N$  is selected from the group consisting of hydrogen, optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C_{2-10}$ -alkenyl, optionally substituted  $C_{2-10}$ -alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted  $C_3$ - $C_7$ -cycloalkyl,  $CH_2-N(R^3)(R^3)$ ,  $CH_2-OR^3$ ,  $CH_2-SR^3$ ,  $CH_2-O-C(=O)R^3$ ,  $CH_2-O-C(=O)-OR^3$ ,  $CH_2-O-C(=S)R^3$ ,  $CH_2-S-C(=O)R^3$ ,  $C(=O)(R^3)$ ,  $C(=S)R^3$ ,  $-C(=S)-OR^3$ , -
- 10  $C(=O)-SR^3$ ,  $C(=O)-N(R^3)(R^3)$ ,  $C(C=S)-N(R^3)(R^3)$ ;

$-A-$  and  $-A'-$  is selected from the group consisting of hydrogen,  $-C(R^2)(R^2)-$ ,  $-C(=O)-$ ,  $-N(R^N)-$ ,  $-O-$ ,  $-S-$ ,  $-P-$ ,  $-P(O)-$ ;

$Y$  and  $Y'$  are each a biradical which may be absent or independently selected from one of the group consisting of optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C(=O)-C_{1-6}$ -

optionally substituted  $C_{2-10}$ -alkynyl, optionally substituted  $C_{3-8}$ -carbocycle and optionally substituted heterocycle;

$Y$  and  $Y'$  are each a biradical which may be absent or independently selected from one of the group consisting of optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C(=O)-C_{1-6}$ -

- optionally substituted aryl, optionally substituted heteroaryl, optionally substituted  $C_{3-8}$ -
- 20 carbocycle, optionally substituted heterocycle,  $H$ ,  $OR^2$ ,  $N(R^2)(R^3)$ ,  $S-R^2$ ,  $NO_2$ ,  $-CN$ , and halogen;

wherein  $R^2$  is selected from the group consisting of hydrogen, optionally substituted  $C_{1-4}$  alkyl, optionally substituted  $C_{2-5}$  alkenyl, optionally substituted  $C_{2-6}$  alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and

- 25 optionally substituted  $C_3$ - $C_7$  cycloalkyl;

$n$  is a whole number and  $m$  is a whole number, and wherein

$R^2$  and  $R^3$  are independently selected from the group consisting of hydrogen, halogen, hydroxy, optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C_{2-5}$  alkenyl, optionally substituted  $C_{2-6}$  alkynyl, optionally substituted aryl, optionally substituted heteroaryl,

- 30 optionally substituted heterocycle, and optionally substituted  $C_3$ - $C_7$  cycloalkyl.

Accordingly, the present invention relates to a method of treating diseases and disorders for which inhibition or modulation of the topoisomerase II enzyme produces a physiologically beneficial response in said disease or disorder comprising the step of

35 administering an effective amount of a compound of formula I, as described *supra*.

Compounds of the formula I, as topoisomerase inhibitors may be effective, in themselves, in the treatment of an array of forms of cancers. A method of treating cancer using

compounds of formula I is a further aspect of the present invention as is the use of compound of formula I for preparation of a medicament for the treatment of cancer.

Furthermore, compounds of the formula I, as topoisomerase inhibitors, may serve to broaden the therapeutic index of other chemotherapeutic agents. Compounds of the present invention may serve to reduce side effects associated with other chemotherapeutic agents or by enhancing the effect of the chemotherapeutic agents. Thus, a further aspect of the present invention relates to the use of compounds of formula I in combination with at least one other chemotherapeutic agent for the effective treatment of cancer.

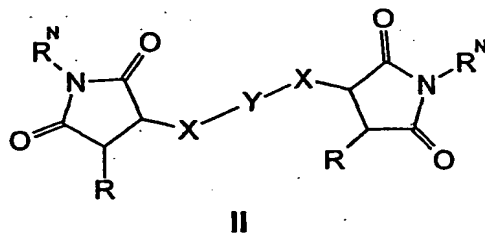
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Compounds of formula I are topoisomerase II catalytic inhibitors and, as such, may be used as pharmacological regulators of topoisomerase II which are exploited in a number of applications according to the present invention including the following:

1. To achieve dose escalation of classical topoisomerase II poisons such as etoposide (VP-16) to treat refractory solid tumours;
2. To target the cytotoxicity of known topoisomerase II poisons to acid microenvironments such as solid tumours;
3. To reduce the tissue destructive effect of known anticancer agents including topoisomerase II poisons in accidental extravasation occurring in the course of cancer treatment in general;
4. To act as anti-tumour agents in themselves by means of inhibiting essential topoisomerase II catalytic activity.

25 Thus, the compounds of formula I may be used in a method of preventing or treating tissue damage due to extravasation in an individual. The use of compounds of formula I as anti-extravasation agents is an important aspect of the present invention.

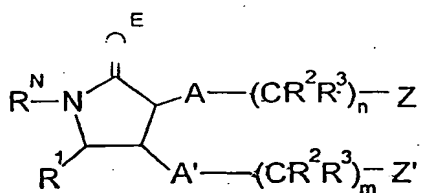
A further aspect of the present invention relates to compounds of formula II for use as  
30 medicament,





wherein Y is a biradical independently selected from the group consisting of C1-6-alkyl, C(=O)-C1-6-alkyl, C1-6-alkyl-C(=O), C2-10-alkenyl, C2-10-alkynyl, C3-8-carbocycle, heterocycle, each of which may be optionally substituted; X is selected from the group consisting of N(R<sup>2</sup>), O, and S; R<sup>N</sup> is selected from the group consisting of hydrogen, optionally substituted C1-8 alkyl, optionally substituted C2-10-alkenyl, optionally substituted C2-10 alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted C3-C7-cycloalkyl, CH<sub>2</sub>-N(R<sup>3</sup>)(R<sup>3</sup>), CH<sub>2</sub>-OR<sup>3</sup>, CH<sub>2</sub>-SR<sup>3</sup>, CH<sub>2</sub>-O-C(=O)R<sup>3</sup>, CH<sub>2</sub>-O-C(=S)R<sup>3</sup>, CH<sub>2</sub>-S-C(=O)R<sup>3</sup>, C(=O)(R<sup>3</sup>), C(=S)R<sup>3</sup>, -C(=S)-OR<sup>3</sup>, -C(=O)-SR<sup>3</sup>, C(=O)-N(R<sup>3</sup>)(R<sup>3</sup>), C(C=S)-N(R<sup>3</sup>)(R<sup>3</sup>); R and R<sup>2</sup> are independently selected from the group consisting of hydrogen, optionally substituted C1-6 alkyl, optionally substituted C2-6 alkenyl, optionally substituted C2-6 alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C3-C7 cycloalkyl.

the invention relates to compounds of formula II:

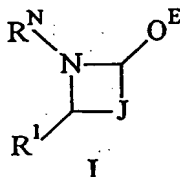


III

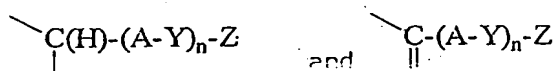
wherein R<sup>N</sup> is selected from the group consisting of hydrogen, CH<sub>2</sub>-N(R<sup>4</sup>)(R<sup>4</sup>), CH<sub>2</sub>-OR<sup>4</sup>, and CH<sub>2</sub>-O-C(=O)R<sup>4</sup>; A and A' are independently selected from the group consisting of N(R<sup>4</sup>)(R<sup>5</sup>) and O; n and m are independently selected whole numbers in the range of 0 to 8, Z and Z' are selected from the group consisting of hydrogen and N(R<sup>2</sup>)(R<sup>4</sup>) wherein R<sup>2</sup> is an optionally substituted heterocycle; -O<sup>E</sup> is a carbonyl equivalent such as selected from the group consisting of =O, =S; -OR<sup>2</sup>, -SR<sup>2</sup>, dithiane, dioxolane and dioxane, R<sup>1</sup> is selected from the group consisting of -O<sup>E</sup>, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>2</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and halogen; R<sup>2</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, halogen, optionally substituted C1-4-alkyl, optionally substituted C2-5-alkenyl, optionally substituted C2-6-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C3-C7-cycloalkyl; R<sup>2</sup>, R<sup>4</sup> and R<sup>5</sup> are independently selected from the group consisting of hydrogen, optionally substituted C1-6 alkyl, optionally substituted C2-5 alkenyl, optionally substituted C2-6 alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C3-C7 cycloalkyl.

# GENERAL DESCRIPTION OF THE INVENTION

As stated, the present invention relates to the use of a compound of formula I, quaternary ammonium salts thereof, or compositions comprising either entity, for the preparation of a human topoisomerase II catalytic inhibitor,



wherein -J- is selected from the group consisting of



-O<sup>E</sup> is a carbonyl equivalent such as selected from the group consisting of =O, =S; -OR<sup>2</sup>, -SR<sup>2</sup>, dithiane and dioxolane;

R<sup>1</sup> is selected from the group consisting of -O<sup>E</sup>, OR<sup>2</sup>, N(R<sup>11</sup>)(R<sup>12</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and halogen;

R<sup>N</sup> is selected from the group consisting of hydrogen, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub>-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted C<sub>3-7</sub>-cycloalkyl, CH<sub>2</sub>-N(R<sup>3</sup>)(R<sup>3</sup>), CH<sub>2</sub>-OR<sup>3</sup>, CH<sub>2</sub>-SR<sup>3</sup>, CH<sub>2</sub>-O-C(=O)R<sup>3</sup>, CH<sub>2</sub>-O-C(=O)-OR<sup>3</sup>, CH<sub>2</sub>-O-C(=S)R<sup>3</sup>, CH<sub>2</sub>-S-C(=O)R<sup>3</sup>, C(=O)(R<sup>3</sup>), C(=S)R<sup>3</sup>, -C(=S)-OR<sup>3</sup>, -C(=O)-SR<sup>3</sup>, C(=O)-N(R<sup>3</sup>)(R<sup>3</sup>), C(C=S)-N(R<sup>3</sup>)(R<sup>3</sup>);

-A- and -A'- is selected from the group consisting of hydrogen, -C(R<sup>2</sup>)(R<sup>2</sup>)-, -C(=O)-, -N(R<sup>N</sup>)-, -O-, -S-, -P-, -P(O)-;

Y and Y' are each a biradical which may be absent or independently selected from one of the group consisting of optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C(=O)-C<sub>1-6</sub>-alkyl, optionally substituted C<sub>1-6</sub>-alkyl-C(=O), optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub>-alkynyl, optionally substituted C<sub>3-8</sub>-carbocycle and optionally substituted heterocycle;

Z and Z' are each a monoradical independently selected from the group consisting of optionally substituted aryl, optionally substituted heteroaryl, optionally substituted C<sub>3-8</sub>-carbocycle, optionally substituted heterocycle, H, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>3</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and halogen;

wherein R<sup>2</sup> is selected from the group consisting of hydrogen, optionally substituted C<sub>1-4</sub> alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally

substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3</sub>-C<sub>7</sub> cycloalkyl;

$n$  is a whole number and  $m$  is a whole number, and wherein

**R<sup>2</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, halogen,**

5 hydroxy, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3</sub>-C<sub>7</sub> cycloalkyl.

In the present context the term "C<sub>1-6</sub>-alkyl" is intended to mean a linear or branched

10 saturated hydrocarbon chain wherein the longest chains has from one to six carbon atoms, such as methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isopentyl, neopentyl and hexyl. A branched hydrocarbon chain is intended to mean a C<sub>1-6</sub>-alkyl substituted at any carbon with a hydrocarbon chain.

double bonds. Examples of C<sub>3-6</sub>-alkenyl groups include allyl, homo-allyl, vinyl, crotyl,

more than one double bond include butadienyl, pentadienyl, hexadienyl, heptadienyl,

20 hexatrienyl, heptatrienyl and octatrienyl groups as well as branched forms of these. The position of the unsaturation (the double bond) may be at any position along the carbon chain and the term is intended to include alkylidene groups.

In the present context the term "C<sub>2-10</sub>-alkynyl" is intended to mean linear or branched

25 hydrocarbon groups containing from two to ten carbon atoms and containing one or more triple bonds. Examples of C<sub>2-10</sub>-alkynyl groups include acetylene, propynyl, butynyl, pentynyl, hexynyl, heptynyl and octynyl groups as well as branched forms of these. The position of unsaturation (the triple bond) may be at any position along the carbon-chain the term is intended to include alkylidyne groups. More than one bond may be unsaturated

30 such that the "C<sub>2-10</sub>-alkynyl" is a di-yne or enedi-yne as it is known to the person skilled in the art.

In the present context the term "C<sub>3-8</sub>-cycloalkyl" is intended to cover three-, four-, five-, six-, seven-, and eight-membered rings comprising carbon atoms only whereas the term

35 "heterocyclyl" is intended to mean three-, four-, five-, six- seven-, and eight-membered rings wherein carbon atoms together with from 1 to 3 heteroatoms constitute said ring. The heteroatoms are independently selected from oxygen, sulphur, and nitrogen.

C<sub>3-8</sub>-cycloalkyl and heterocyclyl rings may optionally contain one or more unsaturated bonds situated, however, in such a way that an aromatic  $\pi$ -electron system does not arise.

Examples of preferred "C<sub>3-8</sub>-cycloalkyl" are the carbocycles cyclopropane, cyclobutane, 5 cyclopentane, cyclopentene, cyclopentadiene, cyclohexane, cyclohexene, 1,3-cyclohexadiene, 1,4-cyclohexadiene, cycloheptane, cycloheptene, 1,2-cycloheptadiene, 1,3-cycloheptadiene, 1,4-cycloheptadiene and 1,3,5 cycloheptatriene.

Examples of "heterocycles" are the heterocycles 2*H*-thiopyran, 3*H*-thiopyran, 4*H*-thiopyran, 10 tetrahydrothiopyran, 2*H*-pyran, 4*H*-pyran, tetrahydropyran, piperidine, 1,2-dithiin, 1,2-dithiane, 1,3-dithiin, 1,3-dithiane, 1,4-dithiin, 1,4-dithiane, 1,2-dioxin, 1,2-dioxane, 1,3-dioxin, 1,3-dioxane, 1,4-dioxin, 1,4-dioxane, piperazine, 1,2-oxathiin, 1,2-oxathiane, 4*H*-1,3-oxathiin, 1,3-oxathiane, 1,4-oxathiin, 1,4-oxathiane, 2*H*-1,2-thiazine, tetrahydro-1,2-thiazine, 2*H*-1,3-thiazine, 4*H*-1,3-thiazine, 5,6-dihydro-4*H*-thiazine, 4*H*-1,4-thiazine,

4*H*-1,3-oxazine, 4*H*-1,4-oxazine, malonimide, succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, isoxazole, hydantoin,

hexahydro-1,3,5-triazine, tetrahydrothiophene, tetrahydrofuran, pyrroline, pyrrolidine, 20 pyrrolidone, pyrrolidione, pyrazoline, pyrazolidine, imidazoline, imidazolidine, 1,2-dioxole, 1,2-dioxolane, 1,3-dioxole, 1,3-dioxolane, 3*H*-1,2-dithiole, 1,2-dithiolane, 1,3-dithiole, 1,3-dithiolane, isoxazoline, isoxazolidine, oxazoline, oxazolidine, thiazoline, thiazolidine, 3*H*-1,2-oxathiole, 1,2-oxathiolane, 5*H*-1,2-oxathiole, 1,3-oxathiole, 1,3-oxathiolane, 1,2,3-trithiole, 1,2,3-trithiolane, 1,2,4-trithiolane, 1,2,3-trioxole, 1,2,3-trioxolane. 1,2,4- 25 trioxolane, 1,2,3-triazoline and 1,2,3-triazolidine.

In the present context the term "aryl" is intended to mean a carbocyclic aromatic ring or ring system. Moreover, the term "aryl" includes fused ring systems wherein at least two aryl rings, or at least one aryl and at least one C<sub>3-8</sub>-cycloalkyl, or at least one aryl and at 30 least one heterocyclyl, share at least one carbon atom, such as in a spiro system or at least chemical bond, such as in a fused system. Examples of "aryl" rings include optionally substituted phenyl, naphthalenyl, phenanthrenyl, anthracenyl, acenaphthylenyl, tetralinyl, fluorenyl, indenyl, indolyl, coumaranyl, coumarinyl, chromanyl, isochromanyl, and azulenyl. A preferred aryl group is phenyl.

35

In the present context, the term "heteroaryl" is intended to mean an aryl group where one or more carbon atoms in an aromatic ring have been replaced with one or more heteroatoms selected from the group comprising nitrogen, sulphur, phosphorous and oxygen. Furthermore, in the present context, the term "heteroaryl" comprises fused ring

systems wherein at least one aryl ring and at least one heteroaryl ring, at least two heteroaryls, at least one heteroaryl and at least one heterocycdyl, or at least one heteroaryl and at least one C<sub>3-8</sub>-cycloalkyl share at least one chemical bond, such as two chemical bonds. Examples of a heteroaryl may be selected from the group comprising

5 furanyl, thiophenyl, pyrrolyl, phenoxazonyl, oxazolyl, thiazolyl, isothiazolyl, imidazolyl, pyrazolyl, isoxazolyl, imidazolyl isothiazolyl, oxadiazolyl, furazanyl, triazolyl, thiadiazolyl, piperidiny, pyridiny, pyridaziny, pyrimidiny, pyraziny, pyrazolyl and triaziny, isoindolyl, indoliny, benzofuranyl, benzothiophenyl, benzopyrazolyl, indazolyl, benzimidazolyl, benzthiazolyl, puriny, quinoliziny, quinoliny, isoquinoliny, cinnoliny, phthalaziny,

10 quinazoliny, quinoxaliny, naphthyridiny, pteridiny, thienofuranyl, carbazolyl, acridiny, phenaziny, phenothiaziny, phenoxaziny and thianthrenyl.

When used herein the term "C<sub>1-6</sub>-alkoxy" is intended to mean C<sub>1-6</sub>-alkyl-oxy such as methoxy, ethoxy, n-propoxy, isopropoxy, n-butoxy, isobutoxy, sec-butoxy, tert-butoxy,

The term "halogen" includes fluorine, chlorine, bromine and iodine.

In the present context, i.e. in connection with the terms "aryl", "heteroaryl", "C<sub>3-8</sub>-cycloalkyl", "heterocycdyl", "C<sub>1-6</sub>-alkyl", "C<sub>1-6</sub>-alkoxy", "C<sub>2-8</sub>-alkenyl", and "C<sub>2-8</sub>-alkynyl", the

20 term "optionally substituted" is intended to mean that the group in question may be substituted one or several times, such as 1 to 5 times, preferably 1 to 3 times, most preferably 1 to 2 times, with one or more groups selected from C<sub>1-6</sub>-alkyl, C<sub>1-6</sub>-alkoxyl, oxo (which may be represented in the tautomeric enol form), carboxyl, amino, hydroxyl (which

25 when present in an enol system may be represented in the tautomeric keto form), nitro, sulphono, sulphonyl, sulfoxide, C<sub>1-6</sub>-carboxyl, C<sub>1-6</sub>-alkoxycarbonyl, C<sub>1-6</sub>-alkylcarbonyl, formyl, aryl, aryloxy, aryloxycarbonyl, arylcarbonyl, heteroaryl, amino, mono- and di(C<sub>1-6</sub>-alkyl)amino; carbamoyl, mono- and di(C<sub>1-6</sub>-alkyl)aminocarbonyl, amino-C<sub>1-6</sub>-alkyl-aminocarbonyl, mono- and di(C<sub>1-6</sub>-alkyl)amino-C<sub>1-6</sub>-alkyl-aminocarbonyl, C<sub>1-6</sub>-

30 alkylcarbonylamino, cyano, guanidino, carbamido, C<sub>1-6</sub>-alkanoyloxy, C<sub>1-6</sub>-alkylsulphonyloxy, dihalogen-C<sub>1-6</sub>-alkyl, trihalogen-C<sub>1-6</sub>-alkyl, halogen, where aryl and heteroaryl representing substituents may be substituted 1-3 times with C<sub>1-6</sub>-alkyl, C<sub>1-6</sub>-alkoxy, sulfoxide, nitro, cyano, hydroxy, amino or halogen. In general, the above substituents may be susceptible to further optional substitution.

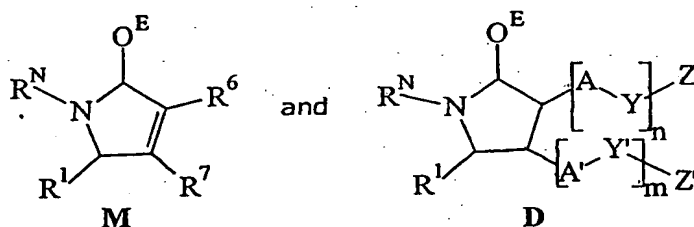
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The term "salts" is intended to mean pharmaceutically acceptable acid addition salts obtainable by treating the base form of a functional group, such as an amine, with appropriate acids such as inorganic acids, for example hydrohalic acids; typically hydrochloric, hydrobromic, hydrofluoric, or hydroiodic acid; sulfuric acid; nitric acid;

phosphoric acid and the like; or organic acids, for example acetic, propionic, hydroacetic, 2-hydroxypropanoic acid, 2-oxopropanoic acid, ethandioic, propanedioic, butanedioic, (Z)-2-butenedioic, (E)-butenedioic, 2-hydroxybutanedioic, 2,3-dihydroxybutanedioic, 2-hydroxy-1,2,3-propanetricarboxylic, methanesulfonic, ethanesulfonic, 2-hydroxyethanesulfonic acid, benzenesulfonic, 4-methylbenzenesulfonic acid, cyclohexanesulfamic, 2-hydroxybenzoic, fumaric acid, 4-amino-2-hydroxybenzoic, and other acids known to the skilled practitioner.

The term "carbonyl equivalent" is intended to mean derivatives of the carbonyl functional group as known to the person skilled in the art and are intended to include alkylated tautomers thereof, protected forms of the functional group and reduced-protected forms of the functional group.

The present compounds of formula I were surprisingly found to be catalytic inhibitors of II, not for cancer treatment. Compounds of formula I can be used, substituted or succinimide derivatives (compounds of formula D), whereas compounds of formula M are particularly preferred, both differing from the known compound, dextrazoxane (dextrazoxane), which is a highly specific topoisomerase II catalytic inhibitor. Compounds of formula I may be selected from the group consisting of compounds of formula M and D



wherein at least one of  $\text{R}^6$  and  $\text{R}^7$  are independently selected from a group consisting of hydrogen, halogen, hydroxy, primary, secondary or tertiary amine, optionally substituted  $\text{C}_{1-6}$ -alkyl, optionally substituted  $\text{C}_{2-5}$ -alkenyl, optionally substituted  $\text{C}_{2-6}$ -alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted  $\text{C}_3\text{-C}_7$  cycloalkyl; and the other of  $\text{R}^6$  and  $\text{R}^7$  is A-Y-Z, as defined supra.

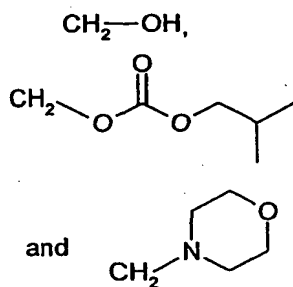
The present investigators have surprisingly found that the compounds of formula M, such as maleimide, NNM and NEM, function as topoisomerase catalytic inhibitors in vitro as well as in intact cells. Contrary to the Wang et al's teaching that NEM increases the level of DNA cleavage with purified topoisomerase II in vitro, the present investigators have found that NEM as well as maleimide does not stimulate DNA cleavage in vitro. On the contrary,

the present inventors find that maleimide and NEM are both capable of antagonising VP-16 induced topoisomerase II mediated plasmid DNA cleavage in vitro. Additionally, the present inventors have found that the compounds of formula M only induce modest levels of DNA damage in NYH cells, at concentrations up to 250  $\mu$ M while expensive DNA damage is provided by 3  $\mu$ M etoposide. Also, in alkaline elution assays, the compound of formula M, maleimide, was found to antagonize DNA damage induced by etoposide, daunorubicin or doxorubicin. Thus, the present inventors find that compounds of formula M behave not as topoisomerase II poisons but rather as topoisomerase II inhibitors.

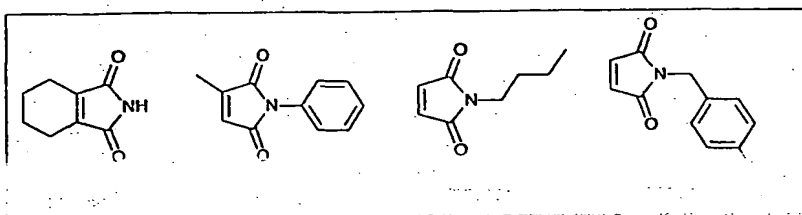
10 This was confirmed in a clonogenic assay where maleimide, N-methyl-maleimide (NMM), N-ethyl-maleimide (NEM) as well as TT0043 effectively blocked the cytotoxicity of etoposide and daunorubicin, providing further evidence that compounds of formula M are catalytic inhibitors of topoisomerase II. Further corroboration of catalytic inhibitory activity of compounds of formula M was found in clonogenic assays on human lung cancer cell lines H595/319 and H595/717 because no resistance to compounds of formula M was found in these cell lines which are selected to be daunorubicin and, etoposide (VP-16) resistant respectively. These lines exhibit cross-resistance to all known topoisomerase II poisons but catalytic topoisomerase II inhibitors.

20 Accordingly, in preferred embodiments of compounds of formula M,  $R^1$  is preferably selected from the group consisting of  $=O^E$  and  $OR^4$ , most preferably wherein  $R^1$  is the carbonyl equivalent  $=O^E$ . As is known to the person skilled in the art, however, carbonyl groups ( $C=O$ ) may be protected so as to dampen their reactivity. Thus, the carbonyl group or groups of compound M may be protected in a manner known to the person skilled in the art, such as its dioxolane or dithiane. Similarly, the carbonyl equivalent may be a thiocarbonyl or protected forms thereof. Alternatively, tautomers of the carbonyl or thiocarbonyl may be prepared and protected with, for instance, an alkyl chain. In a preferred embodiment of compounds of formula M,  $R^1$  is  $=O$ .

30 In a further interesting embodiment of the present invention, the imide nitrogen is derivatized so as to render the compounds of formula M suitable pro-drugs for administration. In suitable embodiment of the compounds,  $R^N$  is selected from the group consisting of hydrogen,  $C_{1-6}$ -alkyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted  $CH_2$ -aryl,  $CH_2-N(R^4)(R^4)$ ,  $CH_2-OR^4$ ,  $CH_2-SR^4$ ,  $CH_2-O-C(=O)R^4$ ,  $CH_2-O-C(=S)R^4$ . In particularly interesting embodiments of compounds of formula M,  $R^N$  is selected from the group consisting of hydrogen, optionally substituted  $C_{1-6}$ -alkyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted  $CH_2$ -aryl, as well as

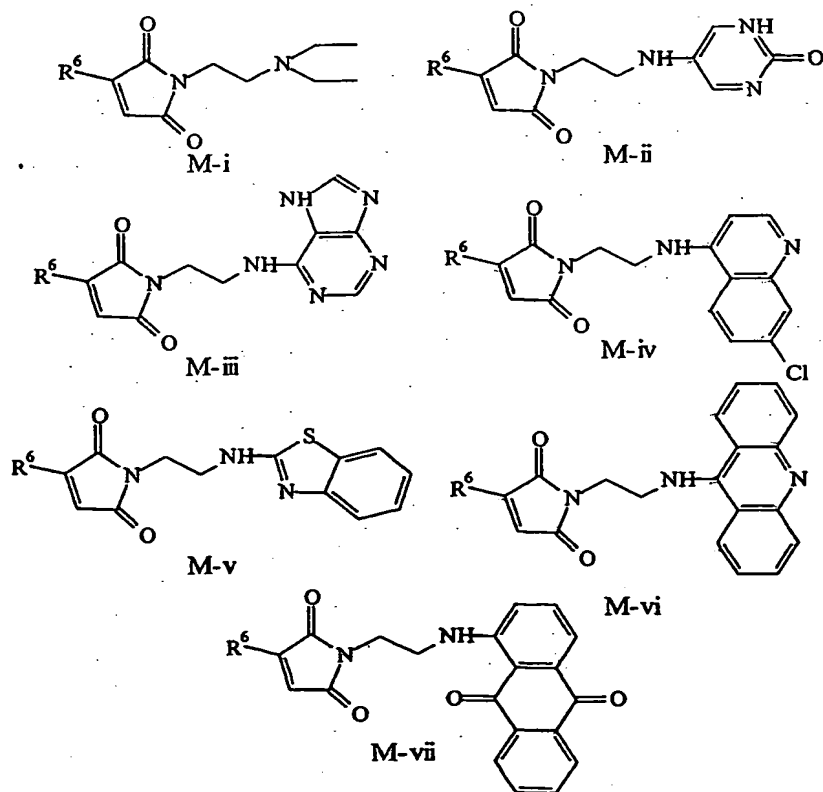


Illustrative embodiments of compounds of formula M demonstrating suitable embodiments of  $\text{R}^N$  are compounds of formula TT0046 (wherein  $\text{R}^N$  is H), TT0048, TT0051 and TT006.



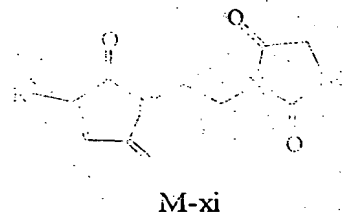
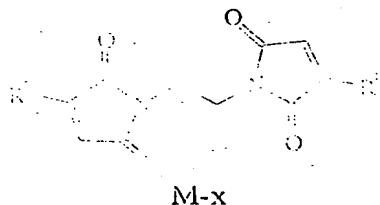
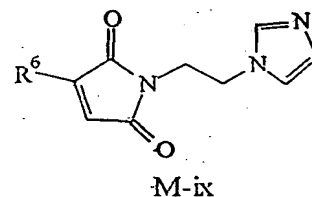
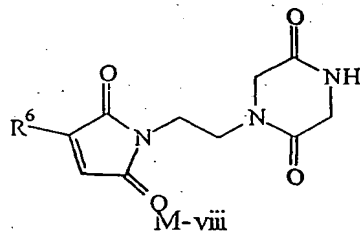
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include M-i, M-ii, M-iii, M-iv, M-v, M-vi and M-vii





In a further suitable embodiments,  $R^N$  is an aliphatic amine wherein the amine nitrogen is part of ring system. Within such interesting embodiments comprises the embodiment comprising a maleimide dimer, linked through their respective imide nitrogens an aliphatic chain. The chain linking two ring systems may be of other chain lengths are further comprise functional groups and substituents, as is known to the person skilled in the art. Suitable embodiments comprise M-viii, M-ix, M-x, and M-xi.



A particular interesting embodiment is wherein  $R^N$  comprises a heterocycle. The heterocycle may be substituted. In a suitable example, the heterocycle is substituted with a substituent which comprises a sulfoxide ( $\text{SO}_3\text{H}$ ,  $\text{SO}_2$ ), a hydroxy, a halogen, or any array of optional substituent as defined supra.

The rings of  $R^N$  may be substituted in a manner known to the person skilled in the art.

In a further preferred embodiment, at least one of  $R^6$  and  $R^7$  is hydrogen. In a combination of preferred embodiments,  $R^1$  is preferably  $=\text{O}$  and at least one of  $R^6$  and  $R^7$  is hydrogen. In such an embodiment, the other of  $R^6$  and  $R^7$  is A-Y-Z, wherein A, Y and Z are as defined supra. In the embodiment wherein at least one of  $R^6$  and  $R^7$  is hydrogen and A is hydrogen, the compound of formula M is maleimide itself.

20

As can be seen from compound TT0046, in a suitable embodiment of compounds of formula M,  $R^6$  and  $R^7$  may together form a ring. Thus,  $R^6$  and  $R^7$  may together form a  $\text{C}_{3-8}$ -carbocycle, heterocycl, aryl or heteroaryl, each of which may optionally be substituted, preferably a  $\text{C}_{3-8}$ -carbocycle, such as cyclohexane.

25

In an interesting embodiment of compounds of formula M,  $\text{O}^E$  is  $=\text{O}$ ,  $\text{R}^1$  is  $=\text{O}$ ,  $\text{R}^N$  is hydrogen, one of  $R^6$  and  $R^7$  is hydrogen, and the other of  $R^6$  and  $R^7$  is optionally

substituted C<sub>1-6</sub>-alkyl, such as selected from methyl (compound TT0043) or ethyl. Various tests were performed on compound TT0043 as illustrated in the Examples.

In the preferred embodiment wherein one of R<sup>6</sup> and R<sup>7</sup> is hydrogen and the other of R<sup>6</sup> and R<sup>7</sup> is A-Y-Z, A may be selected from the group consisting of hydrogen, -C(R<sup>2</sup>)(R<sup>2</sup>)-, -C(=O)-, -N(R<sup>N</sup>)-, -O-, -S-, -P-, -P(O)-; Y may be absent or selected from one of the group consisting of optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C(=O)-C<sub>1-6</sub>-alkyl, optionally substituted C<sub>1-6</sub>-alkyl-C(=O), optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub>-alkynyl, optionally substituted C<sub>3-8</sub>-carbocycle and optionally substituted heterocycle; and Z is a monoradical selected from the group consisting of optionally substituted aryl, optionally substituted heteroaryl, optionally substituted C<sub>3-8</sub>-carbocycle, optionally substituted heterocycle, H, OR<sup>Z</sup>, N(R<sup>Z</sup>)(R<sup>3</sup>), S-R<sup>Z</sup>, NO<sub>2</sub>, -CN, and halogen.

In an interesting embodiment of compounds of formula M, one of R<sup>6</sup> and R<sup>7</sup> is hydrogen and the other of R<sup>6</sup> and R<sup>7</sup> is A-Y-Z wherein Z is selected from the group consisting of N(R<sup>8</sup>)(R<sup>9</sup>) and optionally substituted heteroaryl. In the suitable embodiment Z is an optionally substituted heterocycle, such as a nitrogen-, oxygen-, or sulfur-containing heterocycle. Preferably, the heterocycle is a nitrogen-containing heterocycle. In the embodiment wherein Z is a heterocycle, the heterocycle is preferably selected from the group consisting of maleimide, succinimide, hydantoin, thio-hydantoin, dioxypiperazine, dihydrouracil, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, 3-alkoxyisoxazole, quinoline, aminoacridine, and cytosine, each of which may be optionally substituted. A particular interesting embodiment is wherein R<sup>N</sup> comprises a heterocycle. The heterocycle may be substituted. In the suitable example wherein Z is a heterocycle, said heterocycle is optionally substituted with a substituent which comprises a sulfoxide (SO<sub>3</sub>H, SO<sub>2</sub>), a hydroxy, a halogen, an amine, or any array of optional substituent as defined supra.

In the embodiment wherein Z is a nitrogen-containing heterocycle, said heterocycle may be attached to Y by means of the nitrogen or by means of a carbon atom present in the heterocycle.

As stated, in an interesting embodiment of compounds of formula M, one of R<sup>6</sup> and R<sup>7</sup> is hydrogen and the other of R<sup>6</sup> and R<sup>7</sup> is A-Y-Z wherein Z is selected from the group consisting of N(R<sup>8</sup>)(R<sup>9</sup>), optionally substituted heteroaryl and optionally substituted heterocycl. In the embodiment wherein Z is N(R<sup>8</sup>)(R<sup>9</sup>), R<sup>8</sup> and R<sup>9</sup> may independently be selected from the group consisting of hydrogen, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub>-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted

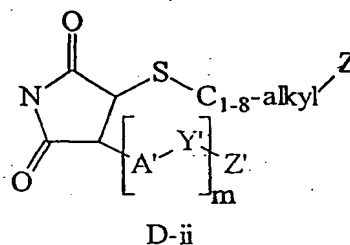
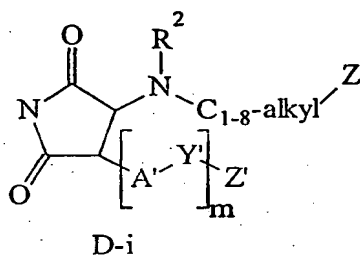
$C_3$ - $C_7$ -cycloalkyl,  $CH_2-N(R^3)(R^3)$ ,  $CH_2-OR^3$ ,  $CH_2-SR^3$ ,  $CH_2-O-C(=O)R^3$ ,  $CH_2-O-C(=O)-OR^3$ ,  $CH_2-O-C(=S)R^3$ ,  $CH_2-S-C(=O)R^3$ ,  $C(=O)(R^3)$ ,  $C(=S)R^3$ ,  $-C(=S)-OR^3$ ,  $-C(=O)-SR^3$ ,  $C(=O)-N(R^3)(R^3)$  and  $C(C=S)-N(R^3)(R^3)$ . In a preferred embodiment, at least one of  $R^8$  and  $R^9$  is selected from the group consisting of optionally substituted heteroaryl and optionally substituted heterocycle, preferably an optionally substituted heterocycle. The present investigators have prepared compounds of formula M wherein Z is  $N(R^8)(R^9)$  and one of  $R^8$  and  $R^9$  is an optionally substituted heterocycle is preferably selected from the group consisting of adenine, benzothiazole, maleimide, succinimide, hydantoin, thio-hydantoin, dioxypiperazine, dihydrouracil, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, 3-alkoxyisoxazole, quinoline, aminoacridine, and cytosine, each of which may be optionally substituted. In the suitable example wherein one of  $R^8$  and  $R^9$  is an optionally substituted heterocycle, said heterocycle is optionally substituted with a substituent which comprises a sulfoxide ( $SO_3H$ ,  $SO_2$ ), a hydroxy, a halogen, an amine, or any array of optional substituent as defined supra.

15

As stated, the compound of formula I may be a compound of formula C, a 2-substituted succinimide. Substitution at the 2-position may be by an optionally substituted alkyl, an amine, an ether or a thioether such that A is preferably  $N(R^2)$ , O, and S. In embodiments of compounds of formula D, the 3-position is preferably substituted with an amine, an ether or a thioether such that A is preferably  $N(R^2)$ , O, and S, most preferably  $N(R^2)$  and S. In a most preferred embodiment, compounds of formula D is a 3-amino succinimide, such that A is  $N(R^2)$ .

Substitution at the 3-position of compounds of formula D may be by a chain of any array of lengths such that amine, ether, thioether or alkyl at the 3-position is bonded to Y wherein Y is biradical which may be absent or independently selected from of the group consisting of optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C(=O)-C_{1-6}$ -alkyl, optionally substituted  $C^{1-6}$ -alkyl- $C(=O)$ , optionally substituted  $C_{2-10}$ -alkenyl, optionally substituted  $C_{2-10}$ -alkynyl, optionally substituted  $C_{3-8}$ -carbocycle and optionally substituted heterocycle. Preferably, Y is selected from the group consisting of  $C_{1-6}$ -alkyl,  $C_{2-10}$ -alkenyl,  $C_{2-10}$ -alkynyl, each of which may be optionally substituted. In a most preferred embodiment of compounds of formula D, Y is optionally substituted  $C_{1-6}$ -alkyl biradical. It is particularly preferable that Y is optionally substituted  $C_{1-6}$ -alkyl, such as a biradical of methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isopentyl, neopentyl and hexyl.

Thus, in a combination of preferred embodiment of compounds of formula D, a 3-substituted succinimide, substituted with a secondary amine, a tertiary amine or thioether (thioxide) wherein the amine or alkoxide is substituted with an optionally substituted C<sub>1-6</sub>-alkyl biradical. That is to say, that in this combination of preferred embodiments of  
 5 compounds of formula D, the class is represented by D-i and D-ii. A particularly preferred embodiment of compound D is compound D-i.



The distal terminus of the substitution at the 3-position of compound D consists of the monoradical Z, which may be selected from the group consisting of optionally substituted  
 10 aryl, optionally substituted heteroaryl, C<sub>3-8</sub>-carbocycle, heterocycle, H, OR<sup>Z</sup>, N(R<sup>Z</sup>)(R<sup>3</sup>), S-R<sup>Z</sup>, NO<sub>2</sub>, -CN, and halogen.

Z is selected from the group consisting of hydrogen, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted C<sub>3-8</sub>-carbocycle, optionally substituted  
 15 heterocycle, OR<sup>Z</sup>, N(R<sup>Z</sup>)(R<sup>3</sup>), S-R<sup>Z</sup>, preferably wherein Z is selected from the group consisting of hydrogen, optionally substituted heteroaryl, optionally substituted heterocycle and N(R<sup>Z</sup>)(R<sup>3</sup>), most preferably optionally substituted heterocycle and N(R<sup>Z</sup>)(R<sup>3</sup>), particularly an optionally substituted heterocycle.

20 In suitable embodiments of compound D, Z is selected from the group consisting of hydrogen, optionally substituted heterocycle, optionally substituted aryl, and optionally substituted C<sub>3-8</sub>-carbocycle. In one particularly interesting embodiment, Z is an optionally substituted heterocycle. In another particularly interesting embodiment, Z is hydrogen.

25 In the suitable embodiment Z is an optionally substituted heterocycle, such as a nitrogen-, oxygen-, or sulfur-containing heterocycle. Preferably, the heterocycle is a nitrogen-containing heterocycle. The heterocycle is preferably selected from the group consisting of maleimide, succinimide, hydantoin, dioxypiperazine, dihydrouracil, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, and 3-alkoxyisoxazole, each  
 30 of which may be optionally substituted.

In a combination of preferred embodiments, A is  $N(R^2)$ , Y is an optionally substituted  $C_{1-6}$ -alkyl, and Z is hydrogen. The  $C_{1-6}$ -alkyl may be optionally substituted, such as by an alkyl chain, as is demonstrated by compounds I-xii to I-xxxiv, wherein, for illustrative purposes only, Y is a  $C_{1-6}$ -alkyl substituted by a  $C_1$ -alkyl (methyl). It is to be understood that the  $C_{1-6}$ -alkyl, and Y in general, may be optionally substituted otherwise such as by one or more higher alkyls, halogens,  $C_{1-6}$ -alkoxides and hydroxyls.

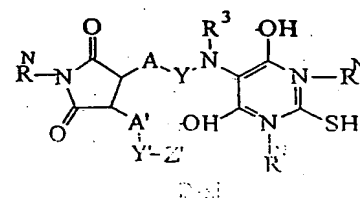
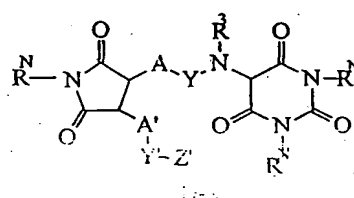
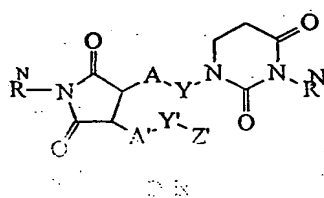
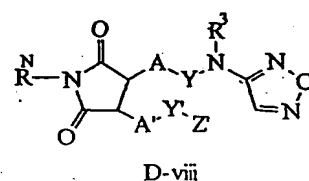
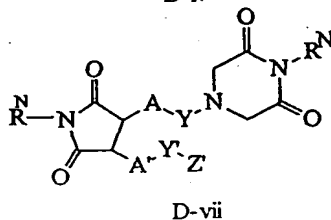
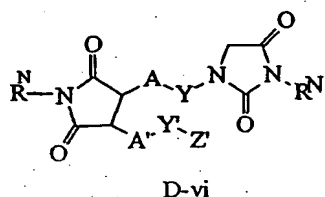
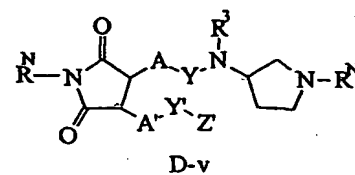
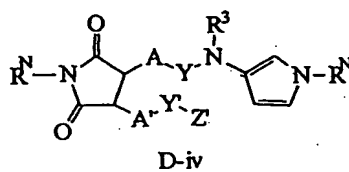
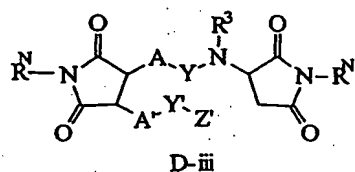
In a further combination of preferred embodiments, A is  $N(R^2)$ , Y is an optionally substituted  $C_{1-6}$ -alkyl, and Z is an optionally substituted heterocycle. In a particularly preferred embodiment, A is  $N(R^2)$ , Y is an optionally substituted  $C_{1-6}$ -alkyl, and Z is maleimide or succinimide.

In a suitable embodiment of compound D, Z is selected from the group comprising of  $OR^Z$ ,  $N(R^Z)(R^3)$ ,  $S-R^Z$ , wherein  $R^Z$  is selected from the group consisting of hydrogen, optionally substituted  $C_{1-4}$  alkyl, optionally substituted  $C_{2-5}$ -alkenyl, optionally substituted  $C_{2-6}$ -alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted  $C_3$ - $C_7$ -cycloalkyl. Preferably,  $R^Z$  is selected from the optionally substituted heterocycle, and optionally substituted  $C_3$ - $C_7$ -cycloalkyl. Most preferably,  $R^Z$  is selected from the group consisting of optionally substituted heteroaryl and optionally substituted heterocycle, most  $R^Z$  is an optionally substituted heterocycle.

In the suitable embodiment wherein  $R^Z$  is an optionally substituted heterocycle, the heterocycle is preferably selected from the group consisting of maleimide, succinimide, hydantoin, dihydrouracil, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, and 3-alkoxyisoxazole, each of which may be optionally substituted.

In a combination of preferred embodiments of compounds of formula D, Z is  $N(R^Z)(R^3)$  and  $R^Z$  is an optionally substituted heterocycle. Most preferably,  $R^Z$  is a heterocycle selected from the group consisting of maleimide, succinimide, hydantoin, dioxopiperazine, imidazole, pyrazole, pyrrole, oxazole and furazan, particularly succinimide. Some suitable embodiments of compound I are illustrated by compounds I-iii to I-xi.

In the suitable embodiment wherein Z is  $N(R^Z)(R^3)$  and  $R^Z$  is an optionally substituted heterocycle, N may be bonded to any position on said heterocycle, including to a heteroatom within said heterocycle.



In a further optional embodiment, Z is  $N(R^2)(R^3)$  and Y is a heterocycle, optionally substituted heterocycle. In such an embodiment N is bonded to Y. Preferably, the heterocycle selected from the group consisting of maleimide, succinimide, hydantoin, thio-hydantoin, dioxypiperazine, dihydropyrimidinone, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, 3-alkoxyisoxazole, quinoline, aminoacridine, and cytosine, each of which may be optionally substituted.

It should be noted that in the combination of interesting embodiments of formula D wherein A is  $N(R^2)$ , Z is  $N(R^2)(R^3)$  and  $R^2$  is succinimide, such as within D-iii, the compound is a dimer of succinimide joined by a linker moiety of length determined by Y. This subclass of compounds showed surprising activity as a topoisomerase II catalytic inhibitor, as shown in Example 1.

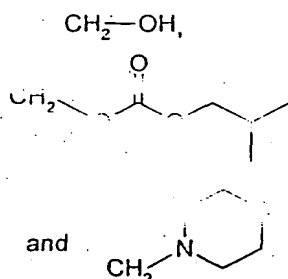
The length of the substituent of compounds of formula D may be altered in part by means of the value of n, which may be any whole number but is preferably an integer ranging from 1 to 3, such as from 1 to 2, preferably 1.

Compounds of formula I, including compounds of formula D, may have the imide nitrogen as the free nitrogen (NH) or may be protected or derivatized with  $R^N$  in a manner known to the person skilled in the art (in the illustrative structures D-iii to I-xii, the imide nitrogen is not defined for simplicity). In a suitable embodiment,  $R^N$  and  $R^M$  are independently selected

from the group consisting of hydrogen, C<sub>1-6</sub>-alkyl, optionally substituted aryl, optionally substituted heteroaryl.

In a further interesting embodiment of the present invention, the imide nitrogen is  
 5 derivatized so as to render the compounds of formula D suitable pro-drugs for administration. In suitable embodiment of the compounds, R<sup>N</sup> and R<sup>M</sup> are selected from the group consisting of hydrogen, CH<sub>2</sub>-N(R<sup>4</sup>)(R<sup>4</sup>), CH<sub>2</sub>-OR<sup>4</sup>, CH<sub>2</sub>-SR<sup>4</sup>, CH<sub>2</sub>-O-C(=O)R<sup>4</sup>, CH<sub>2</sub>-O-C(=S)R<sup>4</sup>, most preferably CH<sub>2</sub>-N(R<sup>4</sup>)(R<sup>4</sup>), CH<sub>2</sub>-OR<sup>4</sup>, and CH<sub>2</sub>-O-C(=O)R<sup>4</sup>.

10 In particularly interesting embodiments of compounds of formula D, R<sup>N</sup> and R<sup>M</sup> are independently selected from the group consisting of hydrogen, optionally substituted C1-6-alkyl,



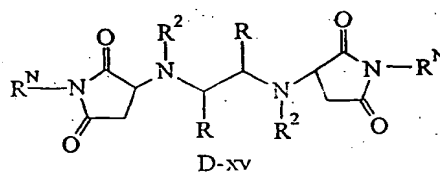
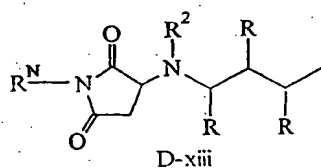
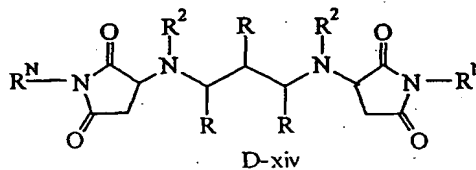
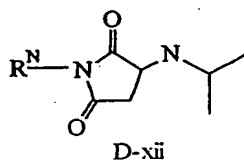
In a suitable embodiment of the present invention, the 4-position of the succinimide  
 15 derivative is also substituted with an A-Y-Z unit as shown in formula D. the value of m may be any whole number, preferably ranging from 0 to 3, such as from 0 to 2, preferably 0 or 1, most preferably 0. In a suitable embodiment, m is 0 and Z' is H.

Thus, in a combination of preferred embodiments of compounds of formula D, m is 0, Z' is  
 20 H, R<sup>1</sup> is O<sup>E</sup>, n is 1, A is N(R<sup>2</sup>), Y is an optionally substituted C1-6-alkyl biradical, Z is N(R<sup>2</sup>)(R<sup>3</sup>) and R<sup>2</sup> is an optionally substituted heterocycle. In another combination of preferred embodiments, m is 0, Z' is H, R<sup>1</sup> is O<sup>E</sup>, n is 1, A is N(R<sup>2</sup>), Y is an optionally substituted C1-6-alkyl biradical, and Z is an optionally substituted heterocycle. The optionally substituted heterocycle is preferably selected from the group consisting of  
 25 succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, hydantoin, and dihydrouracil, dioxopiperazine, each of which may be optionally substituted, most preferably an optionally substituted succinimide.

In an alternative combination of preferred embodiments of compounds of formula D, m is  
 30 0, Z' is H, R<sup>1</sup> is O<sup>E</sup>, n is 1, A is N(R<sup>2</sup>), Y is optionally substituted C1-6-alkyl biradical, and Z is H.

Illustrative examples of these combined preferred embodiments of compounds of formula D are depicted by structures of compounds of the formula D-xii, D-xiii, D-xiv, D-xv, each of which are suitable human topoisomerase II catalytic inhibitors;

5



wherein  $R^N$  is selected from the group consisting of hydrogen, optionally substituted  $C_{1-6}$  alkyl, optionally substituted  $C_{1-6}$ -alkenyl, optionally substituted  $C_{1-6}$ -alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted  $C_3$ - $C_7$ -cycloalkyl,  $CH_2-N(R^3)(R^3)$ ,  $CH_2-OR^3$ ,  $CH_2-SR^3$ ,  $CH_2-O-C(=O)R^3$ ,  $CH_2-O-C(=S)R^3$ ,  $CH_2-S-C(=O)R^3$ ,  $C(=O)(R^3)$ ,  $C(=S)R^3$ ,  $-C(=S)-OR^3$ ,  $-C(=O)-SR^3$ ,  $C(=O)-N(R^3)(R^3)$ ,  $C(C=S)-N(R^3)(R^3)$ ; R is selected from the group consisting of hydrogen, halogen, optionally substituted  $C_{1-6}$  alkyl, optionally substituted  $C_{1-6}$  alkoxy, optionally substituted  $C_{2-5}$  alkenyl, optionally substituted  $C_{2-6}$  alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted  $C_3$ - $C_7$  cycloalkyl;  $R^2$  is selected from the group consisting of hydrogen, optionally substituted  $C_{1-4}$ -alkyl, optionally substituted  $C_{2-5}$ -alkenyl, optionally substituted  $C_{2-6}$ -alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted  $C_3$ - $C_7$ -cycloalkyl.

20

Compound D-xv, wherein R is hydrogen  $R^2$  is hydrogen, and  $R^N$  is hydrogen, known as compound I-21, is tested in the Examples. Compound D-xv, wherein one R is methyl, the other R is hydrogen,  $R^2$  is hydrogen, and  $R^N$  is hydrogen, known as compound I-112, is tested in the Examples.

25

As can also be seen from Example 1, maleimide was surprisingly found to have topoisomerase II catalytic inhibitory activity. Moreover, the 3-aminoalkyl-substituted succinimides were also found to have topoisomerase II catalytic inhibitory activity. Furthermore, "dimeric" compounds wherein two succinimide moieties are linked by an



optionally substituted diamino alkyl chain were also found to have topoisomerase II catalytic inhibitory activity. The present inventors have demonstrated that an array of the maleimide derivatives, 3-substituted succinimides and "dimeric" compounds have topoisomerase II catalytic inhibitory activity. In a most preferred embodiment, compounds  
 5 of formula I are selected from compounds of formula M.

As stated, an important aspect of the present invention relates to a method of treating diseases and disorders for which inhibition or pharmacologic modulation of the topoisomerase II enzyme produces a physiologically beneficial response in said disease or  
 10 disorder comprising the step of administering an effective amount of a compound of formula I. Example 1 demonstrates the activity of selected compounds of formula I as a topoisomerase II catalytic inhibitor. Correspondingly, the use of a compound of formula I for the preparation of a medicament for diseases or disorders for which inhibition or modulation of the topoisomerase II enzyme produces a physiologically beneficial response  
 15 is an important aspect of the present invention. The use of a compound of formula I for the preparation of a medicament for diseases or disorders for which inhibition or modulation of the topoisomerase II enzyme produces a physiologically beneficial response is a particularly important aspect of the present invention.

20 As stated, the topoisomerase II enzymes belong to a family of nuclear enzymes involved in the processing of DNA during the cell cycle. In short, they are able to introduce transient cleavage of both strands of the DNA double helix, thereby allowing the passage of another intact DNA double strand through the cleavage. The duration of the transient DNA break is very short. Topoisomerase II catalytic inhibitors are known to be useful in the treatment of  
 25 tumours. Thus, a further aspect of the present invention relates to a method of treating a tumour in a mammal, such as a human, comprising administering to said mammal an effective amount of a compound of formula I. A method of treating a tumour in a mammal, such as a human, comprising administering to said mammal an effective amount of a compound of formula M is a particularly interesting aspect of the invention. Preferably, the  
 30 anti-tumour effect results, at least in part, by inhibiting topoisomerase II enzyme. A related aspect of the present invention embodies the use of a compound of formula I for the preparation of a medicament for use in anti-cancer therapy. A preferred embodiment of this aspect relates to the use of a compound of formula M for the preparation of a medicament for use in anti-cancer therapy. Accordingly, the compounds of formula I, such  
 35 as compounds of formula M, may be, in themselves, cytotoxic agents, anti-tumour agents or anti-cancer agents.

The compounds of the present invention may be particularly useful in the treatment of tumours such as hypoxic solid tumours. Compounds of the present invention are

anticipated to be particularly useful in the treatment of malignant melanoma, breast cancer, leukaemia and small cell lung cancer. Compounds of the present invention may also be particularly useful for the treatment of tumours which are not especially enriched (poor) in their topoisomerase II concentration.

5

As stated, ICRF-187 is a topoisomerase II catalytic inhibitor. The present investigators have demonstrated that compounds of formula I are also topoisomerase II catalytic inhibitors. Topoisomerase II catalytic inhibitors such as ICRF-187 are useful for the prevention and treatment of accidental extravasation, such as due to topoisomerase  
10 poisons. It is anticipated that topoisomerase II catalytic inhibitors of formula I are useful for the prevention and treatment of accidental extravasation.

Thus, a further aspect of the present invention relates to a method for preventing or treating tissue damage due to extravasation, such as due to topoisomerase II poisons,  
15 including anthracyclines, in a patient receiving said treatment, by administering an effective amount of compound of formula I. A further aspect of the present invention relates to the use of a compound of formula I for the manufacture of an agent to prevent

20 In a suitable embodiment, the extravasation is the result of the administration of one or more topoisomerase II poisons. The topoisomerase poison responsible for the extravasation may be selected from the group comprising doxorubicin, daunorubicin, dactinomycin, epirubicin, bisantrene, paclitaxel, amsacrine, mitomycin C, vincristine, vinblastine, vindesine, liposomal anthracyclines, mitoxantrone, esorubicin, menogaril,  
25 acalcinomycin, cisplatin, fluorouracil, etoposide and bleomycin.

Moreover, the use of the catalytic inhibitors of topoisomerase II of the present invention may enhance the anti-cancer treatment of classical poisons resulting in a broader therapeutic index for the classical poisons by either reducing the side effects (toxicity) or  
30 by enhancing the effect of the poison.

A compound of formula I may be combined with an array of chemotherapeutic agents to provide an effective treatment of a variety of cancers.

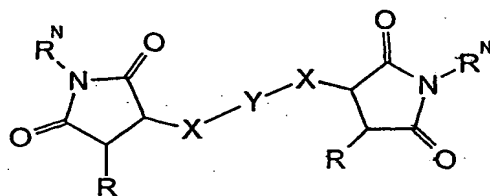
35 However, a particularly interesting aspect of the present invention relates to the use of a compound of formula I, such as a compound of formula D or M, preferably M, as an agent which, when combined with a topoisomerase II poison, is effective in the treatment of cancer and to a method of providing anti-cancer therapy in a mammal, such as a human,

comprising administering an effective amount of a combination of topoisomerase II poison and a compound of formula I, such as a compound of formula D or M, preferably M.

The combination treatment may involve the combining of one or more compounds of formula I, such as a compound of formula D or M, preferably M, with a chemotherapeutic agent be selected from the group comprising paclitaxel, doxorubicin, daunorubicin, dactinomycin, epirubicin, bisantrene, paclitaxel, amsacrine, mitomycin C, vincristine, vinblastine, vindesine, liposomal anthracyclines, mitoxantrone, esorubicin, menogaril, acalcinomycin, cisplatin, fluorouracil, etoposide and bleomycin, mithramycin, melphalan, carmustine, dacarbazine, cytarabine, methotrexate, teniposide, L-asparaginase, alpha-interferon, interleukin 2 and other chemotherapeutic agents known to the person skilled in the art, preferably paclitaxel, doxorubicin, daunorubicin, dactinomycin, epirubicin, bisantrene, paclitaxel, amsacrine, mitomycin C, vincristine, vinblastine, vindesine, liposomal anthracyclines, mitoxantrone, esorubicin, menogaril, acalcinomycin, cisplatin, fluorouracil, etoposide and bleomycin.

Cancers considered to be especially suitable for the combination treatment may be selected from the group comprising malignant melanoma, breast cancer, lung cancer and small cell lung cancer.

A subclass of compounds of formula D, compounds of formula II have never been associated to having therapeutic potential. Thus, a further aspect of the present invention relates to a compound of formula II for use as medicament,

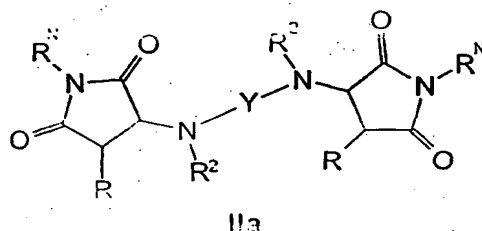


II

wherein Y is a biradical independently selected from the group consisting of C<sub>1-6</sub>-alkyl, C(=O)-C<sub>1-6</sub>-alkyl, C<sub>1-6</sub>-alkyl-C(=O), C<sub>2-10</sub>-alkenyl, C<sub>2-10</sub>-alkynyl, C<sub>3-8</sub>-carbocycle, heterocycle, each of which may be optionally substituted; X is selected from the group consisting of N(R<sup>2</sup>), S and O; R<sup>N</sup> is selected from the group consisting of hydrogen, optionally substituted C<sub>1-8</sub> alkyl, optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub> alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted C<sub>3-7</sub>-cycloalkyl, CH<sub>2</sub>-N(R<sup>3</sup>)(R<sup>3</sup>), CH<sub>2</sub>-OR<sup>3</sup>, CH<sub>2</sub>-SR<sup>3</sup>, CH<sub>2</sub>-O-C(=O)R<sup>3</sup>, CH<sub>2</sub>-O-C(=S)R<sup>3</sup>, CH<sub>2</sub>-S-C(=O)R<sup>3</sup>, C(=O)(R<sup>3</sup>), C(=S)R<sup>3</sup>, -C(=S)-OR<sup>3</sup>, -C(=O)-

$SR^3$ ,  $C(=O)-N(R^3)(R^3)$ ,  $C(C=S)-N(R^3)(R^3)$ ;  $R$  and  $R^2$  are independently selected from the group consisting of hydrogen, optionally substituted  $C_{1-6}$  alkyl, optionally substituted  $C_{2-5}$ -alkenyl, optionally substituted  $C_{2-6}$  alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted  $C_3-C_7$ -cycloalkyl.

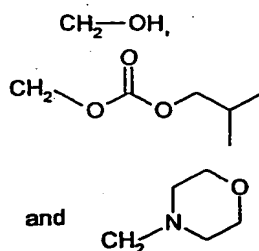
In a preferred embodiment of compound II,  $X$  is selected from the group consisting of  $N(R^2)$  and  $S$ , most preferably  $N(R^2)$  as in compound IIa.



10 In a suitable embodiment, the 4-position of each of the succinimide derivative moieties is unsubstituted. That is to say,  $R$  is suitably hydrogen.

As was stated, in connection with compounds of formula I, derivatization of the imide nitrogen with  $R^N$  in order to prepare pro-drugs is particularly interesting to the present  
 15 investigators.  $R^N$  may be selected from the group consisting of hydrogen,  $CH_2-N(R^4)(R^4)$ ,  $CH_2-OR^4$ ,  $CH_2-SR^4$ ,  $CH_2-O-C(=O)R^4$ ,  $CH_2-O-C(=S)R^4$ , most preferably  $CH_2-N(R^4)(R^4)$ ,  $CH_2-OR^4$ , and  $CH_2-O-C(=O)R^4$ .

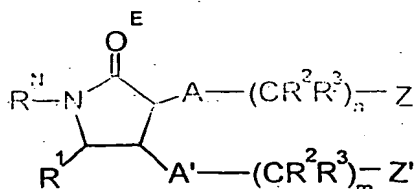
In particularly interesting embodiments of compounds of formula II,  $R^N$  is selected from  
 20 the group consisting of hydrogen,



The succinimide derivative moieties of compounds of formula II are spaced by a  $N(R^2)-Y-N(R^2)$ ,  $O-Y-O$ ,  $S-Y-S$ ,  $N(R^2)-Y-O$ ,  $N(R^2)-Y-S$ ,  $O-Y-S$ ,  $O-Y-N(R^2)$ ,  $S-Y-O$ , or  $S-Y-N(R^2)$  moiety, wherein  $Y$  is a biradical independently selected from of the group consisting of optionally  
 25 substituted  $C_{1-6}$ -alkyl, optionally substituted  $C(=O)-C_{1-6}$ -alkyl, optionally substituted  $C_{1-6}$ -

alkyl-C(=O) and optionally substituted C<sub>3-8</sub>-carbocycle. In a preferred embodiment of compounds of formula II, Y is an optionally substituted C<sub>1-6</sub>-alkyl.

A further aspect of the present invention relates to a subclass of compounds of formula I, termed formula III. These are novel compounds in themselves and have been found to have topoisomerase II catalytic inhibitory activity. Thus the present invention further relates to compounds of formula III



III

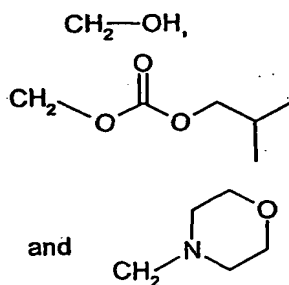
wherein R<sup>N</sup> is selected from the group consisting of hydrogen, and methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isopentyl, neopentyl, and hexyl; CH<sub>3</sub>-O-C(=O)R<sup>4</sup>; A and A' are independently selected from the group consisting of CH<sub>3</sub>, R<sup>5</sup>, S and O; n and m are independently selected from the group consisting of 1 to 8; Z and Z' are selected from the group consisting of hydrogen, optionally substituted heterocycle and N(R<sup>2</sup>)(R<sup>4</sup>) wherein R<sup>2</sup> is an optionally substituted heterocycle; -O<sup>E</sup> is a carbonyl equivalent such as selected from the group consisting of =O, =S; -OR<sup>2</sup>, -SR<sup>2</sup>, dithiane, dioxolane and dioxane; R<sup>1</sup> is selected from the group consisting of -O<sup>E</sup>, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>2</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and halogen; R<sup>2</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, halogen, hydroxy, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>1-6</sub>-alkoxy, optionally substituted C<sub>2-5</sub>-alkenyl, optionally substituted C<sub>2-6</sub>-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3-7</sub>-cycloalkyl; and R<sup>2</sup>, R<sup>4</sup> and R<sup>5</sup> are independently selected from the group consisting of hydrogen, optionally substituted C<sub>1-4</sub> alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3-7</sub> cycloalkyl.

25

In a preferred embodiment of compounds of formula III, (CR<sup>2</sup>R<sup>3</sup>)<sub>n</sub> is selected from the group consisting of optionally substituted C<sub>1-6</sub>-alkyl biradical, preferably optionally substituted C<sub>1-6</sub>-alkyl, such as an optionally substituted biradical of methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isopentyl, neopentyl and hexyl.

30

As stated in connection with compounds of formula I and II, in preferred embodiments of compounds of formula III, R<sup>N</sup> is selected from the group consisting of hydrogen,



In formula III, Z may be an optionally substituted heterocycle selected from the group consisting of succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouracil, and 3-alkoxyisoxazole, each of which may be optionally substituted, preferably wherein Z is an optionally substituted heterocycle selected from the group consisting of succinimide, imidazole, pyrazole, pyrrole, oxazole, and furazan, each of which may be optionally substituted. Most preferably Z is an optionally substituted succinimide.

- 10 In formula III, Z is selected from the group consisting of hydrogen, optionally substituted heterocycle and  $\text{N}(\text{R}^2)(\text{R}^4)$  wherein  $\text{R}^2$  is an optionally substituted heterocycle.

In a preferred embodiments,  $\text{R}^2$  is a heterocycle selected from the group consisting of succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouracil, and 3-alkoxyisoxazole, each of which may be optionally substituted, preferably wherein  $\text{R}^2$  is an optionally substituted heterocycle selected from the group consisting of succinimide, imidazole, pyrazole, pyrrole, oxazole, and furazan, each of which may be optionally substituted. Most preferably  $\text{R}^2$  is an optionally substituted succinimide.

20

In a combination of preferred embodiment of compound of formula III, -A- is  $-\text{N}(\text{R}^4)(\text{R}^5)-$ ,  $\text{R}^1$  is  $-\text{O}^E$  and  $\text{O}^E$  is  $=\text{O}$ , m is 0 and  $\text{Z}'$  is H. In a particularly preferred embodiment of compounds of formula III,  $\text{A}'-(\text{CR}^2\text{R}^3)_m-\text{Z}'$  is H, -A- is  $-\text{N}(\text{R}^4)(\text{R}^5)-$ ,  $\text{R}^1$  is  $-\text{O}^E$  and  $\text{O}^E$  is  $=\text{O}$ .

- 25 In a suitable combination of preferred embodiments of compounds of formula III,  $\text{A}'-(\text{CR}^2\text{R}^3)_m-\text{Z}'$  is H, -A- is  $-\text{N}(\text{R}^4)(\text{R}^5)-$ ,  $\text{R}^1$  is  $-\text{O}^E$ ,  $\text{O}^E$  is  $=\text{O}$ , and Z is hydrogen.

In a suitable combination of preferred embodiments of compounds of formula III,  $\text{A}'-(\text{CR}^2\text{R}^3)_m-\text{Z}'$  is H, -A- is  $-\text{N}(\text{R}^4)(\text{R}^5)-$ ,  $\text{R}^1$  is  $-\text{O}^E$ ,  $\text{O}^E$  is  $=\text{O}$ , and Z is an optionally substituted heterocycle.

30

In an alternative combination of preferred embodiments of compounds of formula III, A'-(CR<sup>2</sup>R<sup>3</sup>)<sub>m</sub>-Z' is H, -A- is -N(R<sup>4</sup>)(R<sup>5</sup>)-, R<sup>1</sup> is -O<sup>E</sup>, O<sup>E</sup> is =O, and Z is N(R<sup>2</sup>)(R<sup>4</sup>) wherein R<sup>2</sup> is an optionally substituted heterocycle.

- 5 In a further suitable combination of preferred embodiments, A'-(CR<sup>2</sup>R<sup>3</sup>)<sub>m</sub>-Z' is H, -A- is -S-, R<sup>1</sup> is -O<sup>E</sup>, O<sup>E</sup> is =O, and Z is N(R<sup>2</sup>)(R<sup>4</sup>) wherein R<sup>2</sup> is an optionally substituted heterocycle.

As stated, compounds of formula D-xii, D-xiii, D-xvi and D-xv were found to have surprising topoisomerase II inhibitory activity. Compounds of formula D-xii, D-xiii, D-xvi  
10 and D-xv are novel compounds. Compounds of formula D-xii, D-xiii, D-xvi and D-xv are a subclass of compounds of formula III and are considered a particularly interesting embodiment of compounds of formula III. Most preferably, R is preferably selected from the group consisting of hydrogen, halogen, hydroxyl, and optionally substituted C<sub>1-4</sub>-alkyl.

enantiomeric, diastereomeric and racemic forms of compounds of the invention are also anticipated.

- 20 A further aspect of the present invention relates to a pharmaceutical composition comprising at least one compound selected from the group consisting of formula I, M, D, II and III, with at least one pharmaceutically acceptable excipient or carrier. Most preferable are compositions comprising compounds of formula M.
- 25 A pharmaceutical composition, according to the present invention, may further comprise one or more chemotherapeutic agents selected from the group comprising paclitaxel, doxorubicin, daunorubicin, dactinomycin, epirubicin, bisantrene, paclitaxel, amsacrine, mitomycin C, vincristine, vinblastine, vindesine, liposomal anthracyclines, mitoxantrone, esorubicin, menogaril, acalcinomycin, cisplatin, fluorouracil, etoposide and bleomycin,  
30 mithramycin, melphalan, carmustine, dacarbazine, cytarabine, methotrexate, teniposide, L-asparaginase, alfa-interferon, Interleukin 2 and other chemotherapeutic agents known to the person skilled in the art, preferably paclitaxel, doxorubicin, daunorubicin, dactinomycin, epirubicin, bisantrene, amsacrine, mitomycin C, vincristine, vinblastine, vindesine, liposomal anthracyclines, mitoxantrone, esorubicin, menogaril, acalcinomycin, cisplatin,  
35 fluorouracil, etoposide and bleomycin.

In a particularly preferred embodiment, pharmaceutical compositions comprise one or more compounds of formula M and further comprise one or more topoisomerase II

poisons. Pharmaceutical compositions may be suitably formulated for oral, mucosal, intravenous, transdermal, parenteral or intracranial administration.

#### BRIEF DESCRIPTION OF THE FIGURES

5

The effect of the compounds of the present invention on the cytotoxicity of some of the classical poisons is illustrated in Figures 1 to 3 showing the results from the clonogenic assays.

- 10 In Figure 1 the effect of ICRF-187 on idarubicin induced cytotoxicity is shown. As seen from the figure, ICRF-187 shows no toxicity to cells when given alone. Idarubicin was used in two different concentrations (0.01 $\mu$ M and 0.03 $\mu$ M). Clearly ICRF-187 was able to inhibit the toxicity induced by idarubicin (0.01mM) up to about 60% survival. Likewise, ICRF-187 has been shown to inhibit the cell toxicity of several other poisons as well.

15

Figure 2 shows the inhibitory effect of the compound I-112 (identical with 105-110, on idarubicin cytotoxicity (same concentrations as mentioned above). I-112 shows no cytotoxicity on its own, but is clearly able to protect against poison induced cell damage. As seen, the concentrations of compound I-112 used are lower than for ICRF-187 (I-112 is thus more potent than ICRF-187 in antagonizing the effect of the topoisomerase II poison idarubicin ), while maximum protection is less than seen for the lead compound ICRF-187.

20

Figure 2 thus demonstrates the ability of compounds of formula I to attenuate the toxic effects of classical poisons such as the prevention of poison-induced cell damage, i.e. extravasation.

25

Figure 3 shows the effective inhibition of poison induced toxicity by the compound of formula M, maleimide. The compound was tested against etoposide (VP-16, in 20 $\mu$ M concentration) and daunorubicin (in 0,3  $\mu$ M concentration). In both cases, the inhibition of cell toxicity was strong, but maleimide is also toxic to cells in itself.

30

Figure 3 thus further demonstrates the ability of compounds of formula M to attenuate the toxic effects of classical poisons such as the prevention of poison-induced cell damage, i.e. extravasation.

35

Figure 3 also demonstrates the ability of compounds of formula M to act as anti-tumour (anti-cancer) agents in themselves.



The effect of the compounds of the present invention on DNA damage conferred by classical poisons is illustrated on Figure 4 and 5 using selected compounds.

As an example, the alkaline elution assay on Figure 4 shows the reversal of etoposide (VP-16) induced SSBs by ICRF-187 and by the compound I-112 (identical with GS-I-3). The promoting effect of etoposide (3 $\mu$ M) on DNA damage is shown on curve 2. The effect of ICRF-187 (500 $\mu$ M) and of I-112 (250 $\mu$ M) when tested against etoposide is seen in the curves 3 and 5, respectively.

10 Clearly, these catalytic inhibitors of topoisomerase II are able to antagonise the SSBs induced by etoposide.

Figure 5 illustrates the ability of maleimide to antagonize etoposide-induced DNA damage in intact cells. Curve 1 is a no drug control, the etoposide effect alone is seen from curve 2. The effect of maleimide (100 $\mu$ M) is seen on curve 5. This antagonism is similar to the antagonism seen for the lead compound ICRF-187.

Figure 4 thus further demonstrates the ability of compounds of formula I, particularly those of formula M, to attenuate the toxic effects of classical poisons such as the prevention of poison-induced cell damage, i.e. extravasation.

Figure 5 thus demonstrates the ability of compounds of formula M (maleimide derivatives) to attenuate the toxic effects of classical poisons such as the prevention of poison-induced cell damage, i.e. extravasation.

Figure 6 illustrates the effect of one of the compounds of the present invention (I-112, identical with GS-I-3) on topoisomerase II catalytic activity using the decatenation assay. Like the control (ICRF-187) compound I-112 is able to inhibit the topoisomerase II catalytic activity effectively at pharmacologically relevant concentrations.

Figure 6 thus demonstrates the ability of compounds of formula I to act as anti-tumour (anti-cancer) agents in themselves.

35 Figure 7 shows the result from a decatenation assay performed with maleimide, NMM and NEM. Clearly, these compounds are highly active on the enzyme having an IC<sub>50</sub> of about 2 $\mu$ M. for Maleimide and about 4  $\mu$ M for NMM and NEM.

Figure 7 thus demonstrates the ability of compounds of formula M to act as anti-tumour (anti-cancer) agents in themselves.

Figure 8 shown the result of a plasmid cleavage assay. Maleimide is found to antagonize etoposide induced formation of linear DNA (form III) at concentrations between 5.0 and 625  $\mu$ M.

Figure 9 shows a similar effect of NEM on etoposide induced formation of linear DNA.

Figure 8 and 9 thus demonstrates the ability of compounds of formula M to act as pharmacological regulators of classical topoisomerase II poisons by antagonizing the effect of these.

Figure 10 demonstrates the ability of a compound of formula M, maleimide, to antagonize etoposide induced band depletion effect. The effect of etoposide on the band depletion effect of topoisomerase II is clearly reduced when coapplied with 10  $\mu$ M etoposide. When maleimide is coapplied this effect of etoposide is gradually lost. At 50  $\mu$ M maleimide the band depleting effect of etoposide is completely lost.

Figure 10 thus demonstrates the ability of compounds of formula I to attenuate the effects of classical topoisomerase II poisons allowing for pharmacological regulation of these.

Figure 11 demonstrates the cytotoxicity of a compound of formula M, maleimide, on the human small cell lung cancer cell line NCI-H69 and on its multi drug resistant derivatives NCI-H69/DAU and NCI-H69/VP. No cross resistance is observed as the three cell lines are equally sensitive to maleimide.

Figure 11 thus demonstrates the ability of compounds of formula M to act as anti-tumour (anti-cancer) agents in themselves circumventing the MDR phenotype of cancer cells.

## EXAMPLES

### Example 1: Pharmacological Activity of Selected Compounds

#### 5 Pharmacological Assays

The *in vitro* and *in vivo* pharmacological assays used to characterise the compounds to be claimed as catalytic inhibitors of the topoisomerase II enzyme are as follows: Clonogenic assay, decatenation assay, alkaline elution, band depletion and plasmid cleavage assay.

- 10 These assays cover a range of information and shall, as proof of concept of this class of compounds for the use as catalytic inhibitors of topoisomerase II, very briefly be described:

15

The information derived from the clonogenic assay is cytotoxicity. If a given compound is able to antagonize the cytotoxic effect caused by the inhibition of catalytic topoisomerase II and classical topoisomerase II poisons, the compound is classified as a catalytic topoisomerase II inhibitor (CI). For medical use, the catalytic inhibitors should only be  
20 cytotoxic in relatively high concentrations by themselves.

- A 3-week clonogenic assay is used. Briefly, single cell suspensions ( $2 \times 10^4$  cells/mL) in RPMI 1640 supplemented with 10% fetal calf serum are exposed to the drugs for 1 h, washed twice in PBS at 37°C, and plated in triplicate in soft agar on top of a feeder layer  
25 containing sheep red blood cells. The number of cells is adjusted to obtain 2000 to 3000 colonies in the control dishes. Finally, the colonies are counted.

#### *Decatenation assay*

- 30 The decatenation assay is a direct measurement of a given compounds inhibitory action on purified topoisomerase II enzyme. The general role of the topoisomerase II enzyme in living cells is to cause decatenation of catenated DNA during cell division. If a compound is able to inhibit this decatenation, the compound is an inhibitor of the topoisomerase II enzyme. While this assay is capable of determining whether a given compound is active  
35 against topoisomerase II, information concerning the exact mode of action is not provided.

Topoisomerase II catalytic activity is measured by kDNA decatenation.  $^3\text{H}$  labelled kDNA is isolated from *Crithidia fasciculata* (ATCC, Manassas, VA) as described in (24). Briefly, relevant concentrations of the test compound in buffer (50mM Tris-Cl, pH8, 120mM KCl, 10mM  $\text{MgCl}_2$ , 1.0mM ATP, , 30mg BSA/ml) and purified topoisomerase II  $\alpha$  is incubated with 0.2 mg kDNA for 15 min at 37°C in a final volume of 20  $\mu\text{L}$ . After addition of stop buffer/loading dye mix (5% Sarkosyl, 0.0025% bromophenol blue, 25% glycerol), samples are loaded on 1% agarose/0.5% ethidium bromide gels and run in TBE buffer containing 0.5 mg/ml ethidium bromide at 100V for approximately 50 min and photographed under UV light. In addition, loading wells are cut out and scintillation counted to obtain numerical values. These values are then plotted against drug concentration to obtain dose-response curves enabling the determination of  $\text{IC}_{50}$  values for individual compounds.

#### *Alkaline elution*

In alkaline elution, which is a whole cell assay (in vitro assay), the compounds are tested in cells for their ability to interfere with the formation of single strand DNA breaks (SSBs) induced by classical poisons e.g. etoposide and daunorubicin. This assay thus provides information concerning a given compounds ability to cause (or antagonize in the case of topoisomerase II catalytic inhibitors in the combination with classical topoisomerase II poisons) DNA damage in intact cells.

The assays for SSBs and for DPCs (DNA-protein cross-links) are performed according to Kohn et. al (23).

For measurement of single-strand breaks (SSBs), L1210 cells used as internal standard are exposed to 100  $\mu\text{M}$   $\text{H}_2\text{O}_2$  for 60 min on ice, corresponding to an irradiation dose of 300 rad as described by Szmigiero and Studzian (25). OC-NYH cells are incubated in medium supplemented with the indicated drug at 37°C for the specified periods, washed in 10 mL ice-cold PBS and then lysed on the filter (Nucleopore, 2.0  $\mu\text{M}$  pore size) with 5 mL of SDS-EDTA lysis solution (2% SDS, 0.1 glycine and 0.025 M  $\text{Na}_2\text{EDTA}$ ) at pH 10, followed by addition of 1.5 mL SDS-EDTA lysis solution supplemented with 0.5 mg/mL proteinase K. Mixing of standard and experimental cells is done immediately prior to lysis. DNA was eluted with tetrapropyl-ammoniumhydroxide-EDTA, pH 12.1 containing 0.1% SDS at a rate of 0.125 mL/min. Fractions are collected at 20-min intervals for 2 h. Filters are treated with 400  $\mu\text{L}$  1 N HCl for 1 h at 60°C, cooled and 0.4 M NaOH is added prior to scintillation counting.

Compounds capable of antagonizing the DNA damage induced by classical topoisomerase II poisons such as etoposide are classified as topoisomerase II catalytic inhibitors.

### Band depletion

5

The band depletion assay is also related to the mode of action of the compounds at the enzyme level in intact cells. Incubation of the cell, with e.g. etoposide, reduces the amount of extractable topoisomerase II  $\alpha$  enzyme in the cells (27). Thus by inhibiting religation, etoposide traps the enzyme on its DNA substrate, leaving less freely available enzyme for  
10 salt extraction. Experiments with the catalytic inhibitor ICRF-187 (preincubated 1 h) has shown (8) that the compound is also able to induce a marked decrease (ATP-dependant) in the extractable amount of both topoisomerase II  $\alpha$  and  $\beta$  isozymes. A correlation between these results and the mode of action of the bisdioxopiperazines acting by locking the homodimeric topoisomerase II in the form of a closed bracelet surrounding the DNA at the

OC-NYH cells are incubated for 1 h at 37°C in RPMI 1640 with 10% of fetal calf serum with the desired compounds for test. Thereafter, whole cell lysates were obtained at 4°C. Exponentially growing cells were harvested and washed in PBS. Cells are then added to

20 0,2 mL ELB-buffer (NaCl 0,25 M, NP40 0,1%, HEPES 50mM, EDTA 5mM) containing aprotinin 1 $\mu$ g/ml, leupeptin 1  $\mu$ g/ml, DTT 1 $\mu$ M and PMSF 0,3 mM and lysed for 30 min. Pellets are spun down at 20000  $\times g$  for 20 min. The protein concentration of the supernatants is measured, and the supernatants are diluted with an equal volume of glycerol.

25

After heating the nuclear extracts for 5 min at 95°C, the sample is immediately loaded on a 7% SDS-PAGE gel containing 5% glycerol. Thereafter, all steps are performed at RT. The separated proteins are transferred to Trans-Blot® Nitrocellulose, in a Mini Trans-blot® Electrophoretic Transfer Cell with 25mM Tris, 192mM glycine and 205v/v methanol, pH 8,3  
30 at 210 mA for 1 h. Membranes are blocked in 10% milk in TBS-T for 1 h and probed with either topoisomerase II  $\alpha$  (1:1000) 1 h. Horseradish-peroxidase-conjugated donkey-antirabbit antibodies are used as secondary antibodies. The blots are developed using ECL™ reagent 1 min and thereafter exposed on films for 5 min. Quantification of can be made by densitometric scanning.

35

While this assay is not capable of demonstrating directly whether a given compound is a topoisomerase II catalytic inhibitor (ICRF-187 and poisons both induce band-depletion) compounds capable of antagonizing the band depletion effect of classical topoisomerase II inhibitors such as etoposide are classified as topoisomerase II catalytic inhibitors.

### Plasmid Cleavage assay

The plasmid cleavage assay is capable of assessing whether a given compound stimulates topoisomerase II mediated DNA cleavage in the test tube. A modification of the protocol described in (Burden *et al.*, 2001) is used. 350 ng purified human topoisomerase II  $\alpha$ , 400 ng pUC18 DNA, and increasing concentrations of drugs were incubated for 6 min at 37 °C in 20  $\mu$ l topoisomerase II cleavage buffer (10 mM TRIS-HCL pH 7.9, 50 mM NaCl, 50 mM KCl, 5 mM  $\text{CaCl}_2$ , 1 mM EDTA, 15  $\mu$ g/ml BSA and 1 mM  $\text{Na}_2\text{ATP}$ , all from Sigma Chemical Co., St. Louis, MO, USA). Next, the cleavable complex was trapped by adding 2  $\mu$ l 10 % SDS. After vigorous vortexing 1.5  $\mu$ l 0.25 M EDTA and 2  $\mu$ l proteinase K (0.8  $\mu$ g/ml) in proteinase buffer (50 mM Tris-HCL pH = 7.9, 1 mM  $\text{CaCl}_2$ ) was added and the samples vortexed. After a 30 min incubation at 45 °C, 5  $\mu$ l loading buffer (5 % Sarkosyl, 0.0425 % bromophenol blue, 25% glycerol) was added and the samples were exposed to 70 °C for 5 min. The samples were run on agarose gels (1.5 % agarose) at 100 V for 5 hours at 5 V/cm to separate different topological forms of plasmid DNA. Finally the gels were stained in distilled water containing 10  $\mu$ g/ml ethidium bromide for 15 min followed by de-stained in distilled water for one hour before they were photographed in UV light. While some classes of topoisomerase II catalytic inhibitors like the bisdioxopiperazine compounds are not capable of antagonizing the effect of classical topoisomerase II poisons in this assay, any compound capable of doing so such as Maleimide and NEM is classified as a topoisomerase II catalytic inhibitor. Further, compounds not capable of stimulating topoisomerase mediated DNA cleavage while being active in the decatenation assay are also classified as topoisomerase II catalytic inhibitors.

25

### Pharmacological Activity of Selected Compounds

The compounds to be claimed as novel catalytic inhibitors of topoisomerase II have been tested in the pharmacological assays mentioned above. Pharmacological data of selected compounds to be claimed are given below together with a brief explanation of the results. This is to verify the use as catalytic inhibitors of this class of compounds. Data are shown for the bisdioxopiperazine ICRF-187 (for comparison) as well as for the compounds I-21, I-112 and maleimide.

30

	<b>ICRF-187</b>	<b>I-21</b>	<b>I-112</b>
<b>Clonogenic Assay</b>	<p><math>LD_{50} = 750\mu M</math>. Not toxic to cells.</p> <p>Effective inhibitor of the toxicity of the classical poisons (VP16, DAU, IDA).</p> <p>Ex: at <math>500\mu M</math> (IDA(0.01)+ up to 80% survival) and</p>	<p><math>LD_{50} = 750\mu M</math>.</p> <p>Not toxic to cells at pH7.4. Tox at lower pH.</p> <p>Only very weak protection of poisons.</p> <p>Ex: at <math>500\mu M</math> (VP-16(20<math>\mu M</math>)+ up to 1% survival).</p>	<p><math>LD_{10} = 75\mu M</math>.</p> <p>Not toxic to cells.</p> <p>Inhibits the toxicity of poisons (DAU, IDA) at lower conc. than ICRF-187 (more potent), but is weaker in the protection.</p> <p>VPneg.</p> <p>DAU(0.3<math>\mu M</math>)+ up to 20% survival.</p>
<b>Decatenation Assay</b>	<p>Inhibits the topoisomerase II decatenation effectively. <math>IC_{50}</math> about 50 <math>\mu M</math>.</p>	<p>Inhibits the topoisomerase II decatenation from above <math>500\mu M</math>. <math>IC_{50}</math> about 800 <math>\mu M</math>.</p>	<p>Inhibits the topoisomerase II decatenation effectively. <math>IC_{50}</math> about 100 <math>\mu M</math>.</p>

<b>Alkaline Elution</b>	Effective inhibition of VP-16 induced SSBs at 200uM.	No effect on the VP-16 induced SSBs found from 50-500uM.	Effective inhibition of VP-16 induced SSBs at 250uM. Very similar to ICRF-187 profile.
<b>Band depletion</b>	Reversible ATP dependent decrease in the extractable levels of both topoisomerase II $\alpha$ and $\beta$ . Preincubated 50uM.	n.d.	n.d.
<b>Plasmid Cleavage</b>	No stimulation of topoisomerase II mediated DNA cleavage. antagonism of etoposide induced DNA cleavage.	n.d.	n.d.

\*) At a concentration of poison, here Idarubicin, of 0.01  $\mu$ M, ICRF-187 (500  $\mu$ M) is capable of protecting the cells so as to obtain 80 % of survival (maximum protection at the given dose). The + Indicates, that the protection. i.e. log(number of surviving cells) is about 1.



	maleimide	NMM	NEM	TT0043
Clonogenic assay	LD <sub>50</sub> 4uM. Very toxic to cells. Effective inhibitor of the classical poisons; Like ICRF-187. Ex: at 0.5uM (VP-16 (20uM)+	IC <sub>50</sub> 4 uM. Antagonism of etoposide and daunorubicin mediated cytotoxicity is equal to what is observed with Maleimide.	IC <sub>50</sub> 4 uM. No antagonism of etoposide and daunorubicin mediated cytotoxicity is observed	LD <sub>50</sub> = 40 uM. Much less toxic than maleimide, NMM and NEM. Protects against the cytotoxicity conferred by 10 uM etoposide and 0,3 uM daunorubicin.
	up to 10% survival.			
Decatenation	Very potent, inhibiting topoisomerase II catalytic activity with IC <sub>50</sub> of 2 uM.	Very potent, inhibiting topoisomerase II catalytic activity with IC <sub>50</sub> of 5 uM.	Very potent, inhibiting topoisomerase II catalytic activity with IC <sub>50</sub> of 5 uM.	n.d.
Alkaline elution	Effective inhibition of VP-16 induced SSBs at 50uM (better than ICRF-187 at 200uM) Only limited DNA damage at concentrations up to 250 uM	n.d.	Only limited DNA damage at concentrations up to 250 uM. Antagonism of topoisomerase II poisons not determined	n.d.
Band depletion	Decrease in the extractable levels of topoisomerase II Similar profile as	n.d	n.d	n.d.

	for ICRF-187. (50uM). Antagonism of etoposide (100 uM) induced band depletion between 4 and 50 uM			
Plasmid cleavage assay	No evidence of topoisomerase II mediated DNA cleavage up to	n.d.	No evidence of topoisomerase II induced DNA cleavage at	n.d.
	Strong antagonism of etoposide (50 uM) induced DNA cleavage between 5 and 625 uM		antagonism of etoposide (50 uM) induced DNA cleavage between 5 and 625 uM	

## Example 2: Synthesis of Sample Compounds

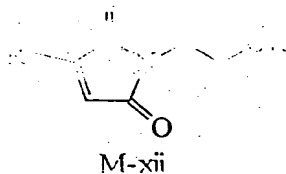
Compounds of the invention may be prepared by the following synthesis:

### 5 General

Maleimides may be prepared in a one-step reaction from readily available anhydrides when treated with a HMDS/methanol reagent in a DMF solution at room temperature.

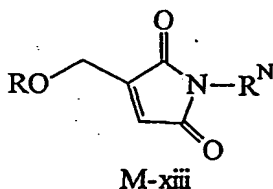
### TT0043

- 10 Compound TT0043 has been synthesised using the general procedure using citraconic anhydride as starting material.



- 15 Compounds of the Type M-xii ( $R^6 = \text{Me}$  as an example) is made using 3-methyl maleic anhydride and ethanol amine as starting materials. Ring closure using acetic anhydride affords the primary alcohol. The alcohol can be converted to various ethers or esters using conventional methods.

### 20 M-xiii



The synthesis of the compounds of formula M-xiii was done in a series of reactions with maleimide as starting material. Initial bromination of the double bond gives 3-bromo-maleimide. Subsequent protection of the carbonyl groups followed by n-BuLi and formalin and deprotection results in 3-hydroxymethyl-maleimide. This compound gives rise to a

- 25 number of reactions. This alcohol can be converted to various ethers or esters using conventional synthetic methods.

Compound (3) can be made, as described above, from a substituted maleic anhydride and ethanol amine. Ring closure to the maleimide structure affords a compound (primary alcohol) which can, upon Mitsunobu reactions using appropriate substituted phenols, give the wanted structure.

5

#### Compounds of the type M-i to M-vii

Compounds of the type M-i to M-vii may be prepared as described for compounds of the type M-xiii using a Mitsunobu coupling reaction to the amino-substituted ring moiety (such as aniline).

10

Compound M-i was prepared in the following manner:

Reaction of this bromide with, as an example, diethyl amine, gives the compound M-i.

Compound M-ii to M-vi were prepared as described for M-i using instead cytosine, adenine, hydantoin, thiohydantoin, imidazole, benzothiazole, aminoacridin or quinoline can give the desired compounds.

20

#### *N,N'*-Di-(pyrrolidine-2',5'-dione-3'-yl)-ethylene-1,2-diamine (I-21)

6.11 g Maleimide (63 mmol) was dissolved in absolute ethanol (75 ml). 2 ml Ethylenediamine (30 mmol) was quickly added at RT. After approximately 5 min., a white precipitate appeared. After 18 hours, the product was collected by filtration, yielding 1.13 g (14.8%) of the title compound.

25

#### *N,N'*-Di-(pyrrolidine-2',5'-dione-3'-yl)-propylene-1,3-diamine (I-14)

30

0.49 g Maleimide (5 mmol) was dissolved in freshly distilled THF (10 ml). 167  $\mu$ l Propylene-1,3-diamine (2 mmol) was added drop wise to the solution. After a short while, the mixture became turbid. After 2 hours, the mixture was evaporated to give an oil. The product was purified by flash chromatography (20% methanol/DCM) to yield 0.35 g (1.3 mmol, 64%) of *N,N'*-di-(pyrrolidine-2,5-dione-3-yl)-propylene-1,3-diamine as an oil.  $^1\text{H}$  NMR (300MHz, DMSO- $d_6$ )  $\delta$  11.06 (s, 2H, 2ximid), 3.63 (dd, 2H, 2xCOCH(CH<sub>2</sub>)N), 2.81 (dd, 2H, 2xCOCHHCH), 2.70 (m, 2H, 2xNCHHCH<sub>2</sub>), 2.50 (m, 2H, 2xNCHHCH<sub>2</sub>), 2.33 (dd, 2H, 2xCOCHHCH), 1.52 (m, 2H, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>).  $^{13}\text{C}$  NMR (75.5MHz, DMSO- $d_6$ )  $\delta$  180.0, 177.1 (C<sub>2</sub>, C<sub>5</sub>), 57.1 (C<sub>3</sub>), 44.9 (C<sub>1</sub>, C<sub>3</sub>), 37.0 (C<sub>4</sub>), 29.9 (C<sub>2</sub>). FAB+ 269.13.

35

**3-*N*-Butylamino-pyrrolidine-2,5-dione (I-10)**

0.37 g *n*-Butyl amine (5 mmol) was dissolved in ethyl acetate (5 ml). The solution was  
 5 cooled to 0°C and 0.48 g maleimide (5 mmol) dissolved in ethyl acetate (15 ml) was added  
 drop wise. After 18 hours, the solvent was evaporated and the product purified by flash  
 chromatography (5% methanol/DCM) to yield 0.82 g (4.82 mmol, 96%) of 3-*N*-  
 butylamino-pyrrolidine-2,5-dione as an oil. <sup>1</sup>H NMR (300MHz, CDCl<sub>3</sub>) δ 3.82 (dd, 1H,  
 COCH(CH<sub>2</sub>)N), 2.95 (dd, 1H, COCHHCH), 2.55-2.73 (m, 3H, NCH<sub>2</sub>CH<sub>2</sub>, COCHHCH), 1.40  
 10 (m, 2H, CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>), 1.38 (m, 2H, CH<sub>2</sub>CH<sub>2</sub>CH<sub>3</sub>), 0.92 (t, 3H, CH<sub>3</sub>).

**3-*N*-Isopropylamino-pyrrolidine-2,5-dione (I-11)**

drop wise. After 48 hours, the solvent was evaporated and the product purified by flash  
 chromatography (5% methanol/DCM) to yield 0.73 g (4.67 mmol, 93%) of 3-*N*-  
 isopropylamino-pyrrolidine-2,5-dione as an oil. <sup>1</sup>H NMR (300MHz, CDCl<sub>3</sub>) δ 3.87 (dd, 1H,  
 COCH(CH<sub>2</sub>)N), 2.92-2.99 (m, 2H, COCHHCH, NCH(CH<sub>3</sub>)<sub>2</sub>), 2.95 (dd, 1H, COCHHCH), 1.11  
 20 (t, 3H, CH<sub>3</sub>).

**4,5,6,7-Tetrahydro-isoindole-1,3-dione (TT0046).**

A solution of 3,4,5,6-tetrahydrophthalic anhydride (330 mg, 2.17 mmol) in DMF (5 ml) was  
 25 treated with a mixture of HMDS (4.6 ml, 21.7 mmol) and methanol (0.5 ml, 10.8 mmol).  
 After 16h at RT the mixture was poured into water and extracted with ethyl acetate. The  
 combined organic layers were washed with water (3 × 12 ml), dried (MgSO<sub>4</sub>), and filtered.  
 Purification by column chromatography using a gradient of 1:1 to 3:1 EtOAc:hexane to  
 give 158.3 mg (48%) of 2: <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 10.47 (broad s, 1H, NH), 2.88  
 30 (m, 4H), 2.72 (m, 4H).

**3-Methyl-1-phenyl-pyrrole-2,5-dione (TT0048).**

A solution of citraconic anhydride (3.74 g, 33.4 mmol) and diethyl ether (4 ml) was placed  
 35 in a 250 ml three-necked flask provided with a reflux condenser. A solution of aniline (3.11  
 g, 33.4 mmol) and ethyl ether (3 ml) was added drop wise. The resulting thick suspension  
 was stirred at RT for 1h and was then cooled in an ice bath. Filtration and drying of the  
 product *in vacuo* gave 6.31 g (92%) of 3-methyl-3-phenylcarbamoyl-acrylic acid, which  
 was used without further purification. A solution of crude 3-methyl-3-phenylcarbamoyl-

acrylic acid (3.00 g, 14.6 mmol), acetic acid (30 ml) and anhydrous sodium acetate was dissolved by swirling and heating in an oil bath for 30 minutes. The reaction mixture was cooled to RT and was poured into 30 ml of ice water. The product precipitated. Filtration, washing of crystals using cold water (3 x 25 ml), cold n-heptane, drying *in vacuo* and purification by column chromatography (ethyl acetate) gave **TT0048** (601 mg (21%) as white needles. <sup>1</sup>H NMR (250 MHz, DMSO-d<sub>6</sub>) δ 7.40 (m, 2H), 7.21 (m, 2H), 7.00 (m, 1H), 6.80 (m, 1H), 2.06 (broad s, 3H). LCMS: 188 (M+1).

#### 1-Butyl-pyrrole-2,5-dione (TT0051)

10

3-Butylcarbamoyl-acrylic acid (864mg; 5.047mmol) was dissolved in acetic anhydride (9ml) containing sodium acetate (800mg). The solution was heated to reflux for 30 min,

the title compound TT0051 (460 mg, 60%) as an oil. <sup>1</sup>H NMR (300MHz, CDCl<sub>3</sub>) δ 6.77 (s, 2H), 3.52 (t, 2H), 1.6 (m, 2H), 1.3 (m, 2H), 0.95 (t, 3H). LC-MS: 154 (M+1).

#### 1-(4-Methoxy-benzyl)-pyrrole-2,5-dione (TT0006).

20

Maleic anhydride (3.02 g, 30.6 mmol) was dissolved in THF (5 ml). 4-Methoxy-phenylamine (4 ml, 30.6 mmol) was added, and the mixture was heated to reflux for 2h. The resulting suspension was cooled to RT, filtered, washed with cold THF (2 x 10 ml), and dried *in vacuo* to give **TT0006** (5.68 g, 85%) <sup>1</sup>H NMR (300 MHz, DMSO-d<sub>6</sub>) δ 9.40 (broad s, 1H, NH), 7.24 (d, 2H), 6.90 (d, 2H), 6.45 (d, 1H, J = 12 Hz), 6.26 (d, 1H, J = 12 Hz), 4.32 (d, 2H, J = 5 Hz), 3.73 (s, 3H).

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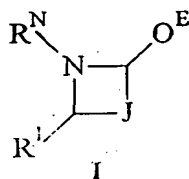
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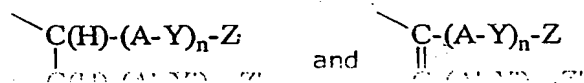


# CLAIMS

1. Use of a compound of formula I, quaternary ammonium salts thereof, or compositions comprising either entity, for the preparation of a human topoisomerase II catalytic inhibitor,



wherein -J- is selected from the group consisting of



-O<sup>E</sup> is a carbonyl equivalent such as selected from the group consisting of =O, =S; -OR<sup>2</sup>, -SR<sup>2</sup>, dithiane and dioxolane;

- 10 R<sup>1</sup> is selected from the group consisting of -O<sup>E</sup>, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>3</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and halogen;

R<sup>N</sup> is selected from the group consisting of hydrogen, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub>-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle,

- 15 optionally substituted C<sub>3-7</sub>-cycloalkyl, CH<sub>2</sub>-N(R<sup>3</sup>)(R<sup>3</sup>), CH<sub>2</sub>-OR<sup>3</sup>, CH<sub>2</sub>-SR<sup>3</sup>, CH<sub>2</sub>-O-C(=O)R<sup>3</sup>, CH<sub>2</sub>-O-C(=O)-OR<sup>3</sup>, CH<sub>2</sub>-O-C(=S)R<sup>3</sup>, CH<sub>2</sub>-S-C(=O)R<sup>3</sup>, C(=O)(R<sup>3</sup>), C(=S)R<sup>3</sup>, -C(=S)-OR<sup>3</sup>, -C(=O)-SR<sup>3</sup>, C(=O)-N(R<sup>3</sup>)(R<sup>3</sup>), C(C=S)-N(R<sup>3</sup>)(R<sup>3</sup>);

-A- and -A'- is selected from the group consisting of hydrogen, -C(R<sup>2</sup>)(R<sup>2</sup>)-, -C(=O)-, -N(R<sup>N</sup>)-, -O-, -S-, -P-, -P(O)-;

- 20 Y and Y' are each a biradical which may be absent or independently selected from one of the group consisting of optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C(=O)-C<sub>1-6</sub>-alkyl, optionally substituted C<sub>1-6</sub>-alkyl-C(=O), optionally substituted C<sub>2-10</sub>-alkenyl, optionally substituted C<sub>2-10</sub>-alkynyl, optionally substituted C<sub>3-8</sub>-carbocycle and optionally substituted heterocycle;

- 25 Z and Z' are each a monoradical independently selected from the group consisting of optionally substituted aryl, optionally substituted heteroaryl, optionally substituted C<sub>3-8</sub>-carbocycle, optionally substituted heterocycle, H, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>3</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and halogen;

wherein R<sup>2</sup> is selected from the group consisting of hydrogen, optionally substituted C<sub>1-4</sub>

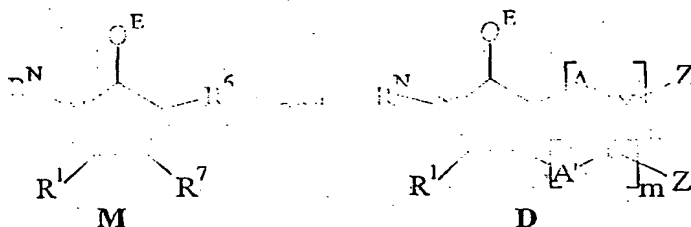
- 30 alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally

substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3</sub>-C<sub>7</sub> cycloalkyl;

n is a whole number and m is a whole number, and wherein

- 5 R<sup>2</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, halogen, hydroxy, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3</sub>-C<sub>7</sub> cycloalkyl.

- 10 2. The use according to claim 1, wherein the compound formula I is selected from the group consisting of compounds of formula M and D:



wherein at least one of R<sup>6</sup> and R<sup>7</sup> are independently selected from group consisting of hydrogen, halogen, hydroxy, primary, secondary or tertiary amine, optionally substituted

- 15 C<sub>1-4</sub>-alkyl, optionally substituted C<sub>2-5</sub>-alkenyl, optionally substituted C<sub>2-6</sub>-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3</sub>-C<sub>7</sub> cycloalkyl;

and the other of R<sup>6</sup> and R<sup>7</sup> is A-Y-Z, as defined in claim 1.

- 20 3. The use according to claim any one of the preceding claims, wherein R<sup>1</sup> is selected from the group consisting of =O<sup>E</sup> and OR<sup>4</sup>, preferably wherein R<sup>1</sup> is =O<sup>E</sup>.

4. The use according to any one of the preceding claims, wherein A is selected from the group consisting of C(R<sup>2</sup>R<sup>3</sup>), N(R<sup>2</sup>), O, and S, preferably N(R<sup>2</sup>), O, and S, most preferably

- 25 N(R<sup>2</sup>) and S.

5. The use according to any one of the preceding claims, wherein Y is selected from the group consisting of C<sub>1-6</sub>-alkyl, C<sub>2-10</sub>-alkenyl, C<sub>2-10</sub>-alkynyl, each of which may be optionally substituted, preferably wherein Y is optionally substituted C<sub>1-6</sub>-alkyl.

30

6. The use according to any of the preceding claims, wherein Z is selected from the group consisting of hydrogen, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted C<sub>3-8</sub>-carbocycle, optionally substituted heterocycle, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>3</sup>), S-

$R^Z$ , preferably wherein Z is selected from the group consisting of hydrogen, optionally substituted heteroaryl, optionally substituted heterocycle and  $N(R^Z)(R^3)$ , most preferably Z is selected from the group consisting of hydrogen, optionally substituted heterocycle and  $N(R^Z)(R^3)$ .

5

7. The use according to claim 2, wherein one of  $R^6$  and  $R^7$  is hydrogen and the other of  $R^6$  and  $R^7$  is A-Y-Z wherein Z is selected from the group consisting of  $N(R^8)(R^9)$  and optionally substituted heteroaryl.

10 8. The use according to any one of claims 6 to 7, wherein the optionally substituted heterocycle is selected from the group consisting of succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouracil, and 3-alkoxyisoxazole, each of which may be optionally substituted, preferably wherein the heterocycle is selected from the group consisting of succinimide, substituted.

9. The use according to claim 1, wherein the compound is of formula M.

20 10. The use according to claim 9, wherein  $R^1$  is =O and at least one of  $R^6$  and  $R^7$  is hydrogen.

11. The use according to claim 9, wherein  $R^6$  and  $R^7$  may together form a ring selected from the group consisting of  $C_{3-8}$ -carbocycle, heterocycyl, aryl or heteroaryl, each of which  
25 may optionally be substituted, preferably a  $C_{3-8}$ -carbocycle, such as cyclohexane.

12. The use according to claim 9, wherein  $O^E$  is =O,  $R^1$  is =O,  $R^N$  is hydrogen, one of  $R^6$  and  $R^7$  is hydrogen, and the other of  $R^6$  and  $R^7$  is  $C_{1-6}$ -alkyl.

30 13. The use according to claim 9, wherein one of  $R^6$  and  $R^7$  is hydrogen and the other of  $R^6$  and  $R^7$  is A-Y-Z, wherein A is selected from the group consisting of hydrogen,  $-C(R^2)(R^2)-$ ,  $-C(=O)-$ ,  $-N(R^N)-$ ,  $-O-$ ,  $-S-$ ,  $-P-$ ,  $-P(O)-$ ; Y may be absent or selected from one of the group consisting of optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C(=O)-C_{1-6}$ -alkyl, optionally substituted  $C_{1-6}$ -alkyl- $C(=O)$ , optionally substituted  $C_{2-10}$ -alkenyl, optionally  
35 substituted  $C_{2-10}$ -alkynyl, optionally substituted  $C_{3-8}$ -carbocycle and optionally substituted heterocycle; and Z is a monoradical selected from the group consisting of optionally substituted aryl, optionally substituted heteroaryl, optionally substituted  $C_{3-8}$ -carbocycle, optionally substituted heterocycle, H,  $OR^Z$ ,  $N(R^Z)(R^3)$ ,  $S-R^Z$ ,  $NO_2$ ,  $-CN$ , and halogen.

14. The use according to claim 9, wherein one of  $R^6$  and  $R^7$  is hydrogen and the other of  $R^6$  and  $R^7$  is A-Y-Z wherein A is selected from the group consisting of hydrogen,  $-C(R^2)(R^2)-$ ,  $-C(=O)-$ ,  $-N(R^4)-$ ,  $-O-$ ,  $-S-$ ,  $-P-$ ,  $-P(O)-$ ; Y may be absent or selected from one of the group consisting of optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C(=O)-C_{1-6}$ -alkyl, optionally substituted  $C_{1-6}$ -alkyl- $C(=O)-$ , optionally substituted  $C_{2-10}$ -alkenyl, optionally substituted  $C_{2-10}$ -alkynyl, optionally substituted  $C_{3-8}$ -carbocycle and optionally substituted heterocycle; and wherein Z is selected from the group consisting of  $N(R^8)(R^9)$ , optionally substituted heteroaryl and optionally substituted heterocycle.

10 15. The use according to claim 14, wherein Z is  $N(R^8)(R^9)$ , wherein  $R^8$  and  $R^9$  may independently be selected from the group consisting of hydrogen, optionally substituted  $C_{1-6}$ -alkyl, optionally substituted  $C_{2-10}$ -alkenyl, optionally substituted  $C_{2-10}$ -alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted  $C_3-C_7$ -cycloalkyl,  $CH_2-N(R^3)(R^3)$ ,  $CH_2-OR^3$ ,  $CH_2-SR^3$ ,  $CH_2-O-C(=O)R^3$ ,  $C(=O)-SR^3$ ,  $C(=O)-N(R^3)(R^3)$  and  $C(C=S)-N(R^3)(R^3)$ , preferably wherein at least one of  $R^8$  and  $R^9$  is selected from the group consisting of optionally substituted heteroaryl and optionally substituted heterocycle, most preferably optionally substituted heterocycle.

20 16. The use according to claim 9 selected from the group consisting of maleimide; NMM, NEM, TT006, TT0043, TT0046, TT0048, TT0051, M-i, M-ii, M-iii, M-iv, M-v, M-vi, M-vii, M-viii, M-ix, M-x, M-xi, M-xii, M-xiii, I-10, I-11, I-14, I-21 and I-112.

17. The use according to any one of the preceding claims, wherein the a human  
25 topoisomerase II catalytic inhibitor is an agent effective in itself in the treatment of cancer.

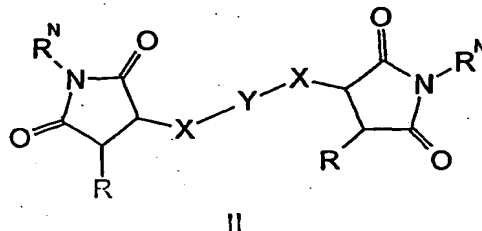
18. The use according to any one of the preceding claims, wherein the a human topoisomerase II catalytic inhibitor is an agent useful in the treatment of extravasation.

30 19. The use according to claim 17, wherein the extravasation is the result of the administration of one or more topoisomerase II poisons.

20. The use according to any one of the preceding claims, wherein the a human topoisomerase II catalytic inhibitor is an agent which, when combined with a  
35 topoisomerase II poison, is effective in the treatment of cancer.

21. The use according to any one of claims 17 and 20, wherein the cancer is selected from the group consisting malignant melanoma, breast cancer, leukaemia and small cell lung cancer.

22. A compound of formula II for use as medicament,



5 wherein Y is a biradical independently selected from the group consisting of C<sub>1-6</sub>-alkyl, C(=O)-C<sub>1-6</sub>-alkyl, C<sub>1-6</sub>-alkyl-C(=O), C<sub>2-10</sub>-alkenyl, C<sub>2-10</sub>-alkynyl, C<sub>3-8</sub>-carbocycle, heterocycle, each of which may be optionally substituted;

X is selected from the group consisting of N(R<sup>2</sup>), O and S;

10 optionally substituted heterocycle, optionally substituted heterocycle, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, optionally substituted C<sub>3-7</sub>-cycloalkyl, CH<sub>2</sub>-N(R<sup>3</sup>)(R<sup>3</sup>), CH<sub>2</sub>-OR<sup>3</sup>, CH<sub>2</sub>-SR<sup>3</sup>, CH<sub>2</sub>-O-C(=O)R<sup>3</sup>, CH<sub>2</sub>-O-C(=S)R<sup>3</sup>, CH<sub>2</sub>-S-C(=O)R<sup>3</sup>, C(=O)(R<sup>3</sup>), C(=S)R<sup>3</sup>, -C(=S)-OR<sup>3</sup>, -C(=O)-SR<sup>3</sup>, C(=O)-N(R<sup>3</sup>)(R<sup>3</sup>), C(C=S)-N(R<sup>3</sup>)(R<sup>3</sup>);

15 R and R<sup>2</sup> are independently selected from the group consisting of hydrogen, optionally substituted C<sub>1-4</sub> alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3-7</sub> cycloalkyl.

20 23. A compound according to claim 22, wherein R is hydrogen.

24. A compound according to claim 22, wherein R<sup>N</sup> is selected from the group consisting of hydrogen, CH<sub>2</sub>-N(R<sup>4</sup>)(R<sup>4</sup>), CH<sub>2</sub>-OR<sup>4</sup>, CH<sub>2</sub>-SR<sup>4</sup>, CH<sub>2</sub>-O-C(=O)R<sup>4</sup>, CH<sub>2</sub>-O-C(=S)R<sup>4</sup>, most preferably CH<sub>2</sub>-N(R<sup>4</sup>)(R<sup>4</sup>), CH<sub>2</sub>-OR<sup>4</sup>, and CH<sub>2</sub>-O-C(=O)R<sup>4</sup>.

25

25. A compound according to claim 22, wherein X is selected from the group consisting of N(R<sup>2</sup>) and S.

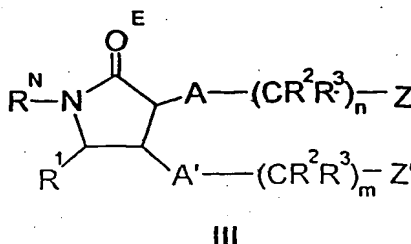
26. A compound according to claim 22, wherein X is N(R<sup>2</sup>).

30

27. A compound according to any of claims 22 to 26, wherein Y is a biradical independently selected from the group consisting of optionally substituted C<sub>1-6</sub>-alkyl, optionally

substituted C(=O)-C<sub>1-6</sub>-alkyl, optionally substituted C<sub>1-6</sub>-alkyl-C(=O) and optionally substituted C<sub>3-8</sub>-carbocycle.

28. A compound of formula III



5

wherein R<sup>N</sup> is selected from the group consisting of hydrogen, CH<sub>2</sub>-N(R<sup>4</sup>)(R<sup>4</sup>), CH<sub>2</sub>-OR<sup>4</sup>, and CH<sub>2</sub>-O-C(=O)R<sup>4</sup>;

A and A' are independently selected from the group consisting of N(R<sup>4</sup>)(R<sup>5</sup>), S and O;

n and m are independently selected whole numbers in the range of 0 to 8

10 Z and Z' are selected from the group consisting of hydrogen, optionally substituted heterocycle, and N(R<sup>2</sup>)(R<sup>4</sup>) wherein R<sup>2</sup> is an optionally substituted heterocycle.

O<sup>E</sup> is a carbonyl, or a radical selected from the group consisting of -H, -H<sub>2</sub>, -H<sub>3</sub>, -SR<sup>2</sup>, dithiane, dioxolane and dioxane,

R<sup>1</sup> is selected from the group consisting of -O<sup>E</sup>, OR<sup>2</sup>, N(R<sup>2</sup>)(R<sup>2</sup>), S-R<sup>2</sup>, NO<sub>2</sub>, -CN, and

15 halogen;

R<sup>2</sup> and R<sup>3</sup> are independently selected from the group consisting of hydrogen, halogen, hydroxy, optionally substituted C<sub>1-6</sub>-alkyl, optionally substituted C<sub>1-6</sub>-alkoxy, optionally substituted C<sub>2-5</sub>-alkenyl, optionally substituted C<sub>2-6</sub>-alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally

20 substituted C<sub>3</sub>-C<sub>7</sub>-cycloalkyl

R<sup>2</sup>, R<sup>4</sup> and R<sup>5</sup> are independently selected from the group consisting of hydrogen, optionally substituted C<sub>1-4</sub> alkyl, optionally substituted C<sub>2-5</sub> alkenyl, optionally substituted C<sub>2-6</sub> alkynyl, optionally substituted aryl, optionally substituted heteroaryl, optionally substituted heterocycle, and optionally substituted C<sub>3</sub>-C<sub>7</sub> cycloalkyl.

25

29. The compound according to claim 28, wherein (CR<sup>2</sup>R<sup>3</sup>)<sub>n</sub> is selected from the group consisting of optionally substituted C<sub>1-6</sub>-alkyl biradical, preferably optionally substituted C<sub>1-6</sub>-alkyl, such as an optionally substituted biradical of methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, tert-butyl, pentyl, isopentyl, neopentyl and hexyl.

30

30. The compound according to claim 28, wherein -A- is -N(R<sup>4</sup>)(R<sup>5</sup>)-.

31. The compound according to claim 28, wherein R<sup>1</sup> is -O<sup>E</sup> and O<sup>E</sup> is =O.

SUBSTITUTE SHEET

32. The compound according to claim 28, wherein m is 0 and Z' is H.

33. The compound according to claim 28, wherein Z is an optionally substituted  
 5 heterocycle selected from the group consisting of maleimide, succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouacil, and 3-alkoxyisoxazole, each of which may be optionally substituted; preferably wherein Z is an optionally substituted heterocycle selected from the group consisting of maleimide, succinimide, imidazole, pyrazole, pyrrole, oxazole, and  
 10 furazan, each of which may be optionally substituted.

34. The compound according to claim 33, wherein Z is selected from the group consisting of an optionally substituted succinimide and optionally substituted maleimide.

35. The compound according to claim 28, wherein R<sup>1</sup> is an optionally substituted heterocycle selected from the group consisting of maleimide, succinimide, imidazole, pyrazole, pyrrole, oxazole, furazan, barbituric acid, thiobarbituric acid, dioxopiperazine, hydantoin, dihydrouacil, and 3-alkoxyisoxazole, each of which may be optionally substituted; preferably wherein R<sup>2</sup> is an optionally substituted heterocycle selected from  
 20 the group consisting of maleimide, succinimide, imidazole, pyrazole, pyrrole, oxazole, and furazan, each of which may be optionally substituted.

36. The compound according to claim 35, wherein R<sup>2</sup> is selected from the group consisting of an optionally substituted succinimide and optionally substituted maleimide.

37. The compound according to claim 28, wherein A'-(CR<sup>2</sup>R<sup>3</sup>)<sub>m</sub>-Z' is H.

38. The compound according to claim 28, wherein R<sup>N</sup> is selected from the group consisting of hydrogen, CH<sub>2</sub>-N(R<sup>3</sup>)(R<sup>3</sup>), CH<sub>2</sub>-OR<sup>3</sup>, and CH<sub>2</sub>-O-C(=O)R<sup>3</sup>.

39. The compound according to claim 28, wherein R is selected from the group consisting of hydrogen, halogen, hydroxyl, and optionally substituted C<sub>1-4</sub> alkyl.

40. A pharmaceutical composition comprising at least one compound selected from the  
 35 group consisting of formula I, formula M, formula D, formula II and formula III, together with at least one pharmaceutically acceptable excipient or carrier.

41. The composition according to claim 40, further comprising one or more chemotherapeutic agents selected from the group consisting doxorubicin, daunorubicin,

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dactinomycin, epirubicin, bisantrene, amsacrine, mitomycin C, vincristine, vinblastine, vindesine, liposomal anthracyclines, mitoxantrone, esorubicin, menogaril, acalcinomycin, cisplatin, fluorouracil, etoposide and bleomycin.

5 42. The composition according to claim 40, further comprising one or more topoisomerase II poisons.

43. The composition according to any one of claims 40 to 42, suitably formulated for oral, mucosal, intravenous, transdermal, parenteral or intracranial administration.

10

44. A method of treating diseases and disorders for which inhibition or modulation of the topoisomerase II enzyme produces a physiologically beneficial response in said disease or disorder comprising the step of administering an effective amount of a compound of formula I, M, II, or III as defined in any one of claims 1 to 39.

45. The method according to claim 44, wherein the disorder is extravasation.

46. The method according to claim 45, wherein the extravasation is due to a topoisomerase II poison.

20

47. The method according to claim 44, wherein the disease is cancer.

48. A method of treating cancer in a mammal, such as a human, comprising administering to said mammal an effective amount of a combination of topoisomerase II poison and a

25 compound of formula I, M, II, or III, preferably a compound of formula M, as defined in any one of claims 1 to 39.



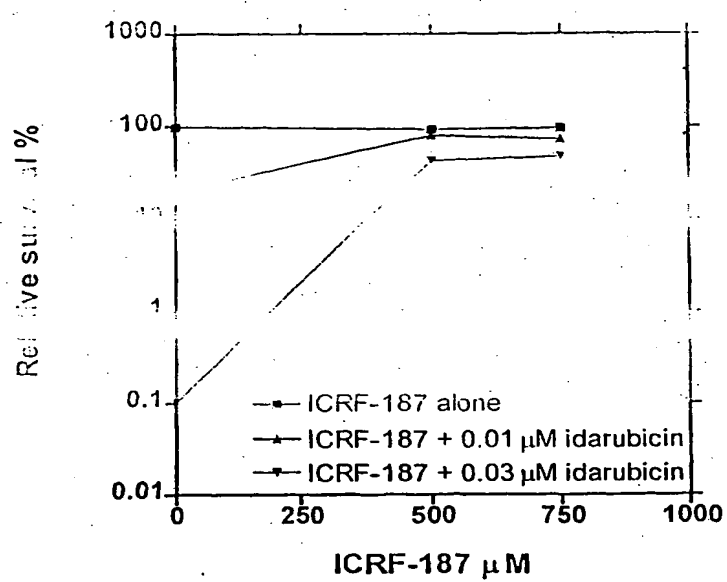


Fig. 1

2/11

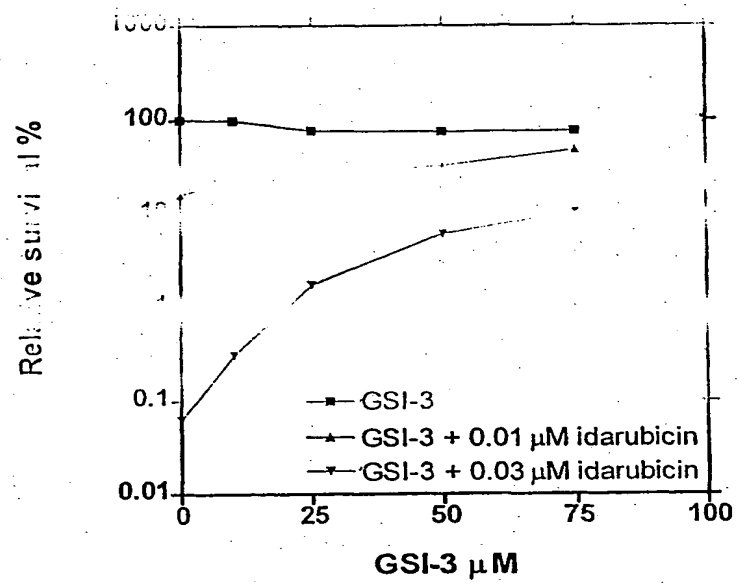


Fig. 2

3/11

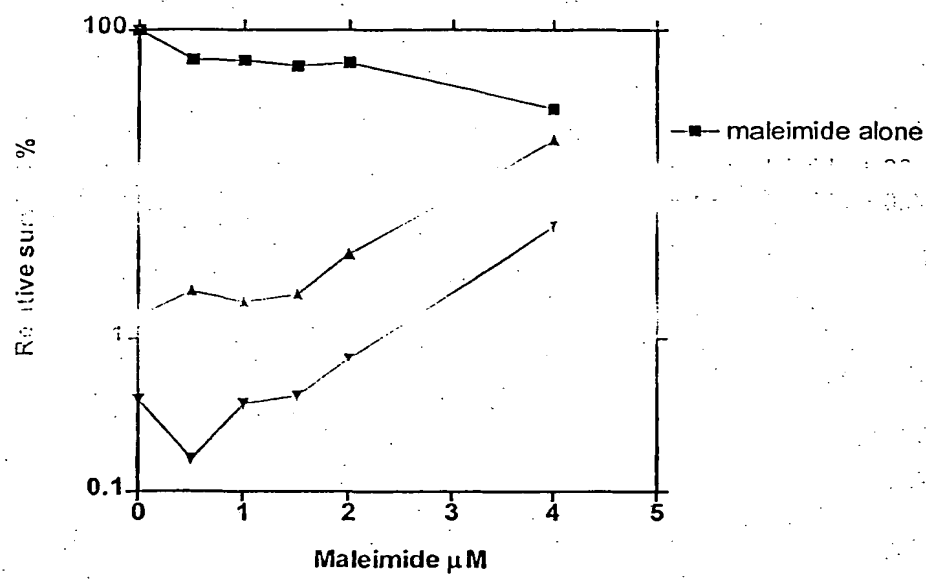


Fig. 3

4/11

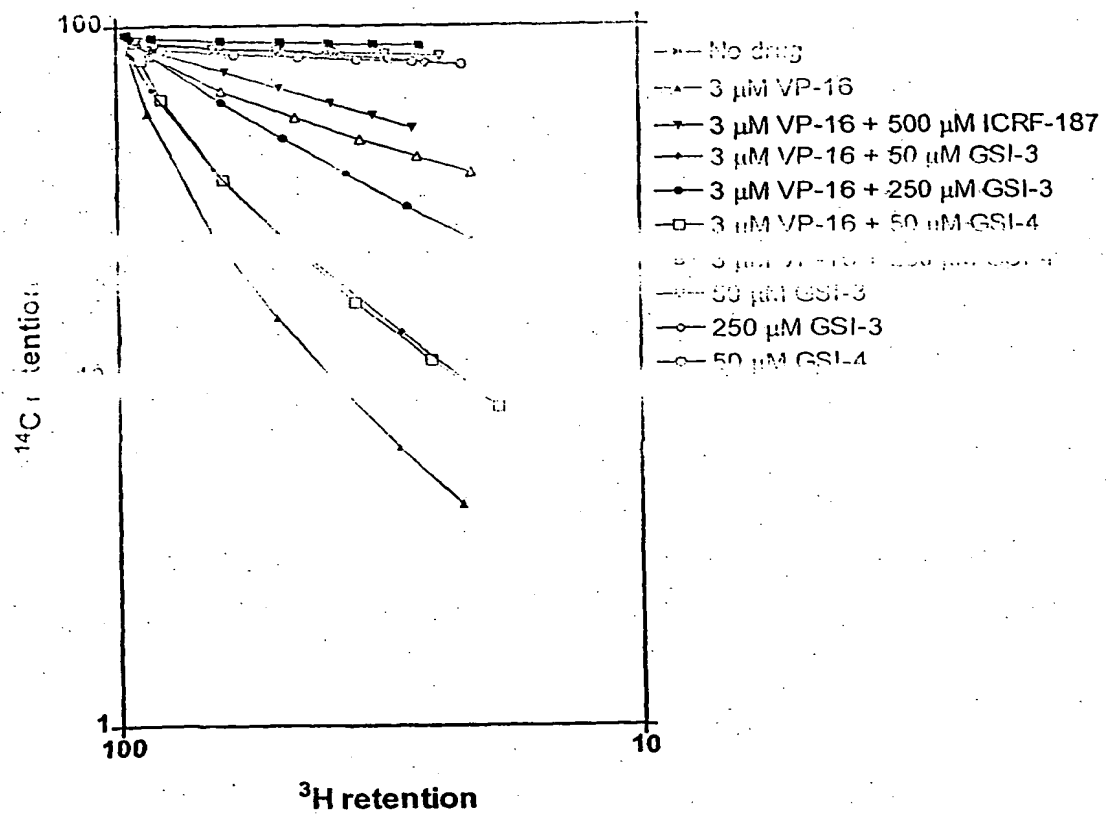


Fig. 4

5/11

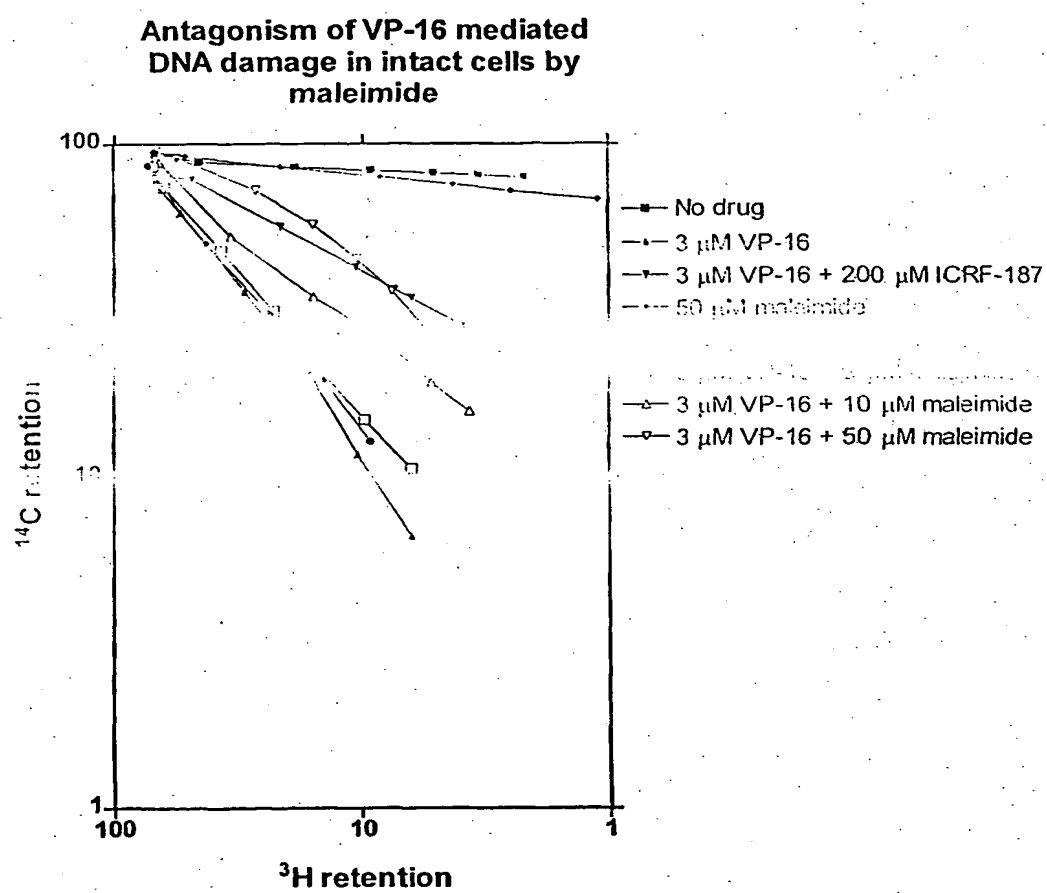


Fig. 5

6/11

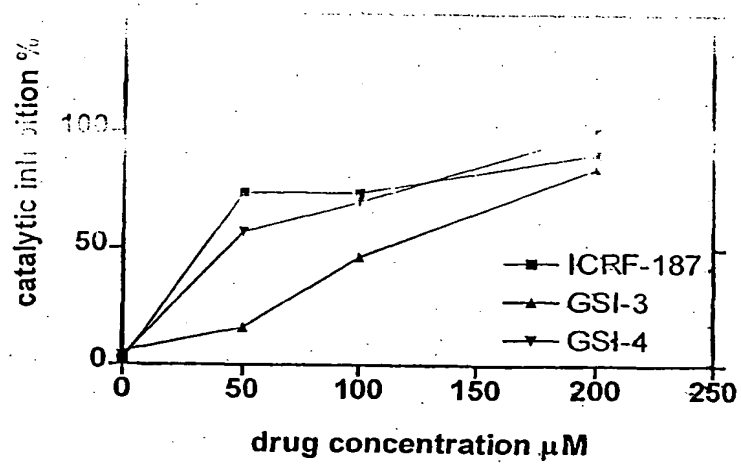


Fig. 6

7/11

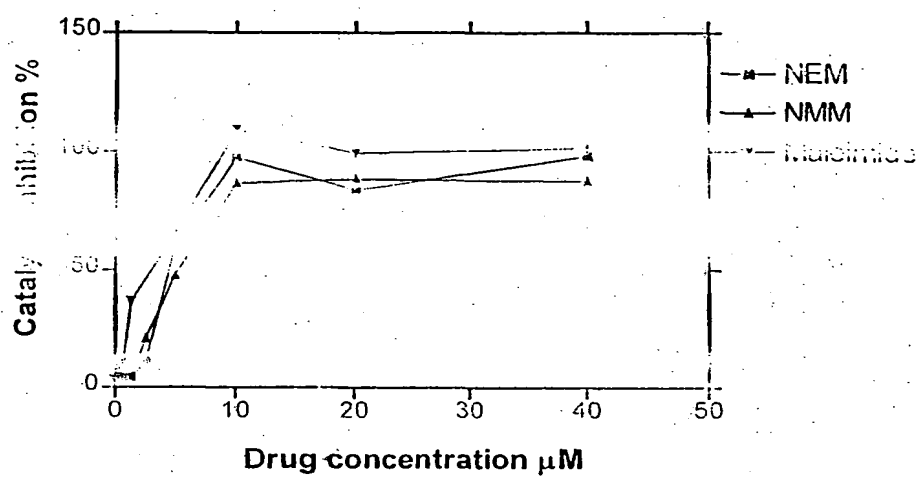


Fig. 7

8/11

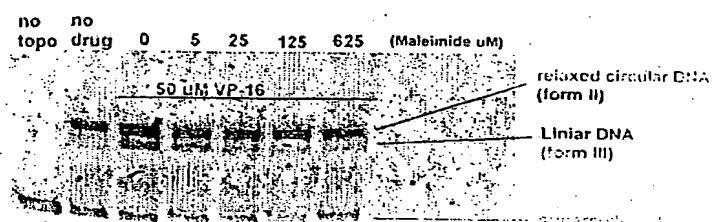


Fig. 8



9/11

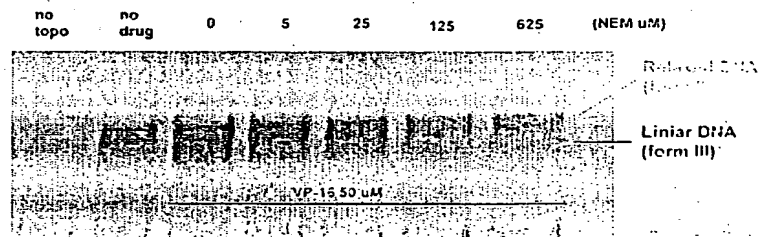


Fig. 9

10/11

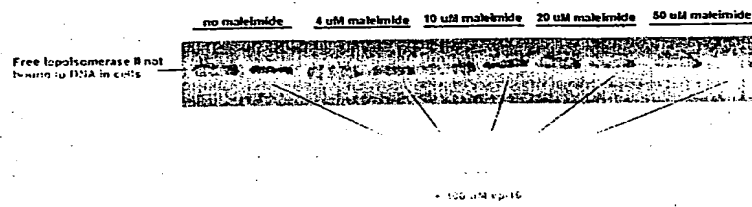


Fig. 10

11/11

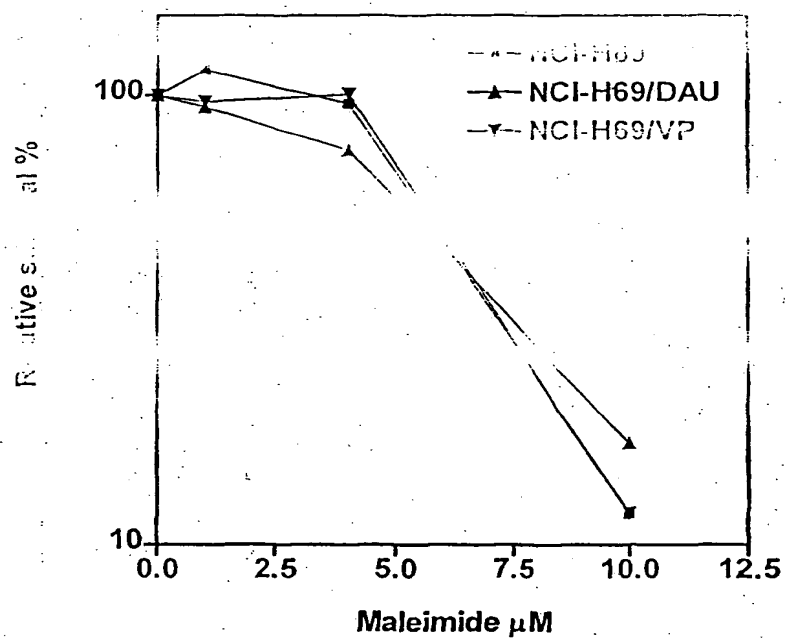


Fig. 11

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European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,

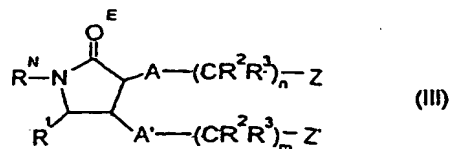
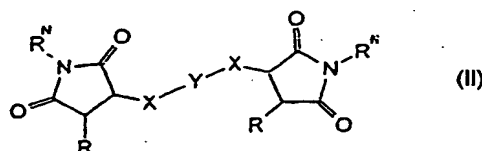
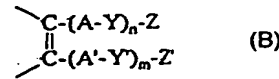
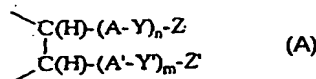
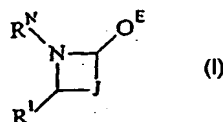
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19 December 2002

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: SUCCINIMIDE AND MALEIMIDE DERIVATIVES AND THEIR USE AS TOPOISOMERASE II CATALYTIC INHIBITORS



(57) Abstract: Maleimide and succinimide derivatives were found to be effective topoisomerase II catalytic inhibitors. Due to this property, the maleimide and succinimide derivatives were investigated for their use as cytostatic agents and thus in the treatment of cancer. The compounds of the invention can be used in combination treatments with other cytostatic agents, such as topoisomerase II poisons. The maleimide and succinimide derivatives, due to their effective topoisomerase II catalytic inhibitory activity, are also useful as extravasation agents, such as upon administration of a topoisomerase II poison. Formula (I), wherein -J- is selected from the group consisting of (A) and (B). A compound of formula (II) for use as medicament. A compound of formula (III).

WO 02/078679 A3

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/DK 02/00213

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C12N9/90 C12N15/10 C07D207/40 A61K31/40 C07D207/44  
C07D207/448

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C12N C07D A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category \* Citation of document, with indication, where appropriate, of the relevant passages

Relevant to claim No.

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figure 1

X

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formulas 6a-b

21-28

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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

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Date of the actual completion of the international search

9 July 2002

Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/DK 02/00213

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 01 87307 A (CELGENE CORP) 22 November 2001 (2001-11-22) claims 1-60 ---	1-14, 39-42
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A	Procedures for "Inhibiting growth of anti-cancer agents." CURRENT PHARMACEUTICAL DESIGN, vol. 3, no. 3, 1997, pages 265-290, XP002902555 figures 21-23 ---	21-28, 39-42
	Reagents for the diagnosis of BIOORGANIC & MEDICINAL CHEMISTRY LETTERS, vol. 4, no. 24, 1994, pages 2845-2850, XP002902556 figure 2, table 1 ---	39-42
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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/DK 02/00213

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>ANIZON F ET AL: "Syntheses and biological activities (topoisomerase inhibition and antitumor and antimicrobial properties) of rebeccamycin analogues bearing modified sugar moieties and substituted on the imide nitrogen with a methyl group." JOURNAL OF MEDICINAL CHEMISTRY, vol. 40, no. 21, 1997, pages 3456-3465, XP002902558 chart 1</p> <p>-----</p>	<p>1-14, 21-28, 39-42</p>

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/DK 02/00213

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 16-20 and 43-47  
because they relate to subject matter not required to be searched by this Authority, namely:  
see FURTHER INFORMATION sheet PCT/ISA/210
2. ☒ Claims Nos.: 1-14, 15 and 39-42  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:  
see FURTHER INFORMATION sheet PCT/ISA/210
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third paragraphs of Rule 29.1.

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☐ No protest accompanied the payment of additional search fees.



## FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

## Continuation of Box I.1

Claims Nos.: 16-20 and 43-47

Claims 16-20 and 43-47 relate to methods of treatment of the human or animal body by surgery or by therapy/diagnostic methods practised on the human or animal body /Rule 39.1.(iv). Nevertheless, a search has been executed for these claims. The search has been based on the alleged effects of the compounds/compositions.

-----

## Continuation of Box I.2

Patent claims 1-14 and 39-42 relate to an extremely large number of possible compounds. In fact, the claims contain so many variable that a lack of clarity and conciseness within the meaning of Article 6 PCT arises to such an extent as to render a search of the prior art impossible. Consequently, the search has been performed on the general idea and has been restricted to the compounds mentioned in the examples of the description.

## Claim 15:

The technical terms employed in claim 15 on page 51 are not generally accepted in the art, contrary to the requirements of Rule 10.1(e) PCT.

## Obvious errors:

1. The numeration of claim 2 covers two different claims (two claims with the same number).
2. The linking of claim 18 to claim 25 must be erroneous. Claim 18 refers to claim 15 and not claim 25.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/DK 02/00213

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/DK 02/00213

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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